LECTURE NOTES

For Environmental and Occupational Health Students

Solid Waste Management

Ethiopia Public Health Training Initiative

Takele Tadesse

University of Gondar

2004

In collaboration with the Ethiopia Public Health Training Initiative, The Carter Center, the Ethiopia Ministry of Health, and the Ethiopia Ministry of Education

Funded under USAID Cooperative Agreement No. 663-A-00-00-0358-00.

Produced in collaboration with the Ethiopia Public Health Training Initiative, The Carter Center, the Ethiopia Ministry of Health, and the Ethiopia Ministry of Education.

Preface

This lecture note will serve as a practical guideline for environmental and occupational health students. I hope that it will be a good resource to solid waste management for health science students working in Ethiopia. Both the students and the practitioners in field of solid waste management will find in this lecture note the basic principles of solid waste management.

There are few books on solid waste management available but hardly, which are written from the perspective of Ethiopia, where majority of population does not have access to proper management of solid waste.

The lecture note basically focused on sources, types and composition of solid wastes; functional elements of solid waste management program; community-based solid waste management; and planning, siting, and permitting of solid waste management facilities. It is written for students who have interest in and responsibility for an integrated solid waste management system to minimize or if possible to eliminate public and environmental health problems so as to prevent diseases and promote health and well being of the community. Its scope is such that it will find application in diploma and degree students.

Acknowledgments

I will be failing in my duty if I do not pay my thanks to those who have helped and encouraged me in upgrading this teaching material.

The author is highly thankful to Carter centre for its overall financial and material help from inception to completion of this teaching material.

I gratefully acknowledge Ato Gabre-Emanuel Teka and Dr.Abera Kumie for giving thorough reading and valuable comments throughout all the chapters.

I wish to express my sincere thanks to the following reviewers whose contributions are reflected throughout this teaching material, particularly to Dr. Mengesha Admassu, Ato Mamo Wubshet, Ato Mulusew Gete, Dr.Bekele Kebede, Ato Alemayehu Haddis and Ato Getachew Redie.

My heart felt thanks goes to Ato Aklilu Mulugeta, W/ro Meseret Yalew and Mahlet Tilahun for facilitating the lecture note preparation process in all dimensions.

My wife S/r. Meseret Senbeto and our son Abel deserves special thanks for their love, encouragement and multiple supports and the burden they shared during this teaching material preparation.

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CHAPTER ONE

INTRODUCTION TO SOLID WASTE MANAGEMENT

1.1. Learning objectives.

By the end of this chapter, the students will be able to:

1. define solid wastes.
2. explain integrated sustainable solid waste management
3. describe scope of solid waste management.
4. explain policy and program matrix on solid waste management.
5. discuss risks and problems associated with solid wastes.

1.2. Introduction

Solid wastes are all the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted. The term solid waste as used in this text is all-inclusive, encompassing the heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulation of agricultural, industrial, and mineral wastes.

From the days of primitive society, humans and animals have used the resources of the earth to support life and dispose of wastes. In early times, the disposal of human and other wastes did not pose a significant problem, because the population was small and the amount of land available for the assimilation of wastes was large. Although emphasis is currently being placed on recycling and fertilizer value of solid wastes, the farmer in ancient times probably made a bolder attempt at this. Indications of recycling may still be seen in the primitive, yet sensible, agricultural practices in many of the developing nations where farmers recycle solid wastes for fuel or fertilizer values.

Problems with the disposal of wastes can be traced from the time when humans first began to congregate in tribes, villages, and communities and the accumulation of wastes became a consequence of life. Littering of food and other solid wastes in medieval towns-the practice of throwing wastes into the unpaved streets, roadways, and vacant land-led to the breeding of rats, with their attendant fleas carrying bubonic plague. The lack of any plan for the management of solid wastes thus led to the epidemic of plague, the Black Death that killed half of the fourteenth – century Europeans and caused many subsequent epidemics with high death tolls. It was not until the nineteenth century that public health officials, who began to realize that food wastes, had to be collected and disposed of in a sanitary manner to control rodents and flies, the vectors of disease.

The relation between public health and improper storage, collection, and disposal of solid wastes is quite clear. Public health authorities have shown that rats, flies, and other disease vectors breed in open dumps, as well as in poorly constructed or poorly maintained housing, in food storage facilities, and in many other places where food and harborage are available for rats and the insects associated with them.

Ecological phenomena such as water and air pollution have also been attributed to improper management of solid wastes. For instance, liquid from dumps and poorly engineered land fills has contaminated surface waters from waste dumps may contain toxic elements, such as copper, arsenic, uranium, or it may contaminate water supplies with unwanted salts of calcium and magnesium. Although nature has the capacity to dilute, disperse, degrade, absorb, or otherwise reduce the impact of unwanted residues in the atmosphere, in the waterways, and on the land, ecological imbalances have occurred where the natural assimilative capacity has been exceeded.

Solid waste management may be defined as the discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accordance with the best principles of public health, economics, engineering, conservations , and that is also responsive to public attitudes.

The nature and operation of solid waste management varies significantly from nation to nation. Distinctions such as these are not limited to the national scale however, and can be seen at the city and neighborhood level. Regardless of scale, these differences are to some extent attributable to prevailing socio-economic, financial, legal and political variables at that level. There is a clear requirement to reconcile the need for more effective waste management with the constraints that are faced by local municipalities or national governments.

The identification of waste management as integral to sustainable urban development is increasingly recognized by the international aid and development community. The United Nations Conference on Environment and Development stressed that '...solid waste production should be minimized, reuse and recycling, maximized, environmentally sound waste disposal and treatment promoted and waste service coverage extended'. UNCHS Habitat emphasizes environmentally sound and resource efficient approaches to the problem of growing solid waste quantities, and considers waste management as a crucial component of human policies and programmes. What these examples illustrate is the rising importance that solid waste management has amongst advocates of sustainable development.

Solid waste management in urban centers of Ethiopia are under the jurisdiction of Municipal Division of Health, all municipalities (except Addis Ababa) and certified urban centers are mandated by Proc. No. 206 of 1981 to provide, maintain and supervise environmental health services along with their other activities in their municipalities and urban centers. Thus, solid wastes management services, are the responsibilities of these municipalities and urban centers. Most of them have no institutional set up and resources for discharging their duties effectively. This is aggravated by the low priority usually accorded to sanitation activities.

The sanitarians assigned to the regional health departments and health centers give technical advice whenever called for besides their routine activities.

Therefore, the material that follows will discuss the major aspects of solid waste management including type, source, and public health and ecological impacts of solid wastes.

1.3 Integrated sustainable solid waste management

What is sustainability in relation to waste management? In the wider perspective sustainability implies looking at the whole waste management system, including waste prevention and resource recovery and searching for a system that best suits the society, economy and environment in question.

Based on a more detailed overview of ten research papers presented from 7 countries largely with the African and Asian context highlighted the following points:

Institutional issues

- Need for policy changes (e.g. legislation) in order to improve effective and efficient solid waste management.
- Need to set up functional structures at the grassroots level to work with communities and institutions
- Need to try to link the formal and informal solid waste management sector through waste collection schemes

Technical issues

- Need to focus more on recycling and resource recovery as a common practice Need to focus on environmental impacts (e.g. surface and ground water) of solid waste around dump sites
- Need for proper management of hospital and hazardous waste
- Need for relevant training and equipment for hospital waste handlers

Sustainable technology for waste management technology choices can be considered at different scales:

1. Choices restricted to technical requirements
    - Waste composition and quantities
    - Area characteristics
    - Haul distances to the disposal site
    - Operational cost
2. Choices with broader perspective
    - Economic conditions
    - Cost of labor
    - Capital
    - Maintenance
    - Repair capacity
    - Skill level of existing staffs
3. Choices looking at the whole waste management system
    - Waste prevention
    - Resource recovery
    - Identifying systems that best suits the society, economy and environment in question

Waste management is often considered to be mainly a technical issue. This misguided approach as resulted in technological choices that are not suitable in the given society, economy and environment. A few examples drawn from experiences in developing countries illustrate this point.

- Municipalities in developing countries purchase new refuse collection equipment with medium to long-term loans (up to 30 years) from foreign donor countries. The equipment usually has operational life of a maximum of 7 years. With poor revenue generating capacity of the sector to service debt, management cost and maintenance this usually leads to crippling debt for the municipality, which continues long after the equipment, is obsolete and thus no longer in use.

- In some countries there has been a policy of standardization of waste collection fleets, with the obvious objective to reduce the cost of maintenance and supervision. The result has been that many areas have been left out, because the streets were too narrow, unpaved, or sloping. These areas usually coincide with low-income neighborhood, located at the urban fringe or in densely populated old city centers. Leaving these areas un-served subsequently affects environmental and public health conditions in the whole city thereby defeating the overall objective of safe solid waste disposal.

- Need to focus on the potential effects of privatization towards various stakeholders involved in solid waste management

Social issues

- Need to work with informal waste actors such as scavengers at dump sites
- Need for health education so as to create awareness regarding solid waste management

1.4. Scope of Solid Waste Management

In its scope, solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in solution to all problems of solid wastes. The solutions may involve complex interdisciplinary relationships among such fields as political science, city and regional planning, geography, economics, public health sociology, demography, communications, and conservation, as well as engineering and material science.

Many people feel that solid waste management is a simple affair - simply putting waste into a vehicle and unloading it at a dump. If this were true, then why do so many towns suffer from uncollected refuse blocking streets and drains, harbouring flies and rats, and degrading urban environments? Successful solid waste management is rarely achieved without thought, effort and much learning from mistakes. The preparation and management of a good solid waste management system needs inputs from a range of disciplines, and careful consideration of local conditions.

1. 5. Risks and Problems Associated with Solid wastes

If solid wastes are not managed properly, there are many negative impacts that may result. Some of the most important are mentioned in the following list. The relative importance of each depends very much on local conditions.

- ❖ Uncollected wastes often end up in drains, causing blockages which result in flooding and unsanitary conditions.
- ❖ Flies breed in some constituents of solid wastes, and flies are very effective vectors that spread disease.
- ❖ Mosquitoes breed in blocked drains and in rainwater that is retained in discarded cans, tires and other objects. Mosquitoes spread disease, including malaria and dengue.
- ❖ Rats find shelter and food in waste dumps. Rats consume and spoil food, spread disease, damage electrical cables and other materials and inflict unpleasant bites.
- ❖ The open burning of waste causes air pollution; the products of combustion include dioxins which are particularly hazardous.
- ❖ Aerosols and dusts can spread fungi and pathogens from uncollected and decomposing wastes.
- ❖ Uncollected waste degrades the urban environment, discouraging efforts to keep streets and open spaces in a clean and attractive condition. Solid waste management is a clear indicator of the effectiveness of a municipal administration - if the provision of this service is inadequate large numbers of citizens (voters) are aware of it. Plastic bags are a particular aesthetic nuisance and they cause the death of grazing animals which eat them.

- Waste collection workers face particular occupational hazards, including strains from lifting, injuries from sharp objects and traffic accidents.
- Dumps of waste and abandoned vehicles block streets and other access ways.
- Dangerous items (such as broken glass, razor blades, hypodermic needles and other healthcare wastes, aerosol cans and potentially explosive containers and chemicals from industries) may pose risks of injury or poisoning, particularly to children and people who sort through the waste.
- Heavy refuse collection trucks can cause significant damage to the surfaces of roads that were not designed for such weights.
- Waste items that are recycled without being cleaned effectively or sterilized can transmit infection to later users. (Examples are bottles and medical supplies.)
- Polluted water (leachate) flowing from waste dumps and disposal sites can cause serious pollution of water supplies. Chemical wastes (especially persistent organics) may be fatal or have serious effects if ingested, inhaled or touched and can cause widespread pollution of water supplies.
- Large quantities of waste that have not been placed according to good engineering practice can slip and collapse, burying and killing people.
- Waste that is treated or disposed of in unsatisfactory ways can cause a severe aesthetic nuisance in terms of smell and appearance.
- Liquids and fumes, escaping from deposits of chemical wastes (perhaps formed as a result of chemical reactions between components in the wastes), can have fatal or other serious effects.
- Landfill gas (which is produced by the decomposition of wastes) can be explosive if it is allowed to accumulate in confined spaces (such as the cellars of buildings).
- Methane (one of the main components of landfill gas) is much more effective than carbon dioxide as a greenhouse gas, leading to climate change.

- ❖ Fires on disposal sites can cause major air pollution, causing illness and reducing visibility, making disposal sites dangerously unstable, causing explosions of cans, and possibly spreading to adjacent property.
- ❖ Former disposal sites provide very poor foundation support for large buildings, so buildings constructed on former sites are prone to collapse.

1.6. Policy and Programme Matrix on Solid Waste Management.

Most local governments and urban agencies have, time and again, identified solid waste as a major problem that has reached proportions requiring drastic measures. Three key trends observed with respect to solid waste are - increase in shear volume of waste generated by urban residents; change in the quality or make-up of waste generated; and the disposal method of waste collected, by land-fill, incineration etc.

It is critical to adopt a broad approach in developing a working framework for solid waste management (solid waste management). This covers the social, economic, technology, political and administrative dimensions. For example the social dimension of solid waste management involves waste minimization; the economic dimension of solid waste management involves waste recycling; the technology dimension of solid waste management involves waste disposal; and the political and administrative dimensions cuts across all the three issues of minimization, recycling and disposal.

Waste Minimization	→	Waste Recycling	→	Waste Disposal
« ···SOCIAL ··· »		« ··· ECONOMIC ··· »		« ··· TECHNOLOGY ··· »

« ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· POLITICAL··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ·· »

« ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ···ADMINISTRATIVE ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· ··· »

Figure 1-1. A working framework for solid waste management.

Source: Source: Adapted from Ref.10

Solid waste management is not an isolated phenomena that can be easily compartmentalized and solved with innovative technology or engineering. It is particularly an urban issue that is closely related, directly or indirectly, to a number of issues such as urban lifestyles, resource consumption patterns, jobs and income levels, and other socio-economic and cultural issues. All these issues have to be brought together on a common platform in order to ensure a long-term solution to urban waste.

There is a whole culture of solid waste management that needs to be put in place - from the micro-level of household and neighborhood to the macro levels of city, state and nation. The general assumption is that solid waste management should be done at the city-level, and as a result, solutions tried out have been essentially end-of-pipe ('End-of-pipe' refers to finding solutions to a problem at the final stage of its cycle of causes and effects). In the case of urban solid waste, it means focusing on solid waste disposal rather than solid waste recycling or solid waste minimization). But this approach essentially misses the forest for the trees, in attempting piece-meal and ad hoc solutions to solid waste problems, instead of taking a long-term holistic approach.

In reality there are a number of critical actions the need to be taken at each of the levels of household, neighborhood, city and nation. Action to be taken can have social, technology, economic, political or administrative dimensions.

It is important that the right decision taken out at the right level. Thus, action at the household level are predominantly social, technology and economic in nature. Similarly actions to be taken at the state and nation level are predominantly economic, political and administrative in nature. Action at the neighborhood and city levels cuts across all five themes.

The matrix that links the dimensions of decision-making (social, technology, economic, political and administrative) with the levels of decision-making (household, neighborhood, city, and nation).It also helps in categorizing the decisions, action and related activities to be undertaken. The Matrix is shown below:

Dimensions and Levels of decision-making	Household	Neighbourhood	City	Nation
Social	*	*	*	
Technology	*	*	*	
Economic	*	*	*	*
Political		*	*	*
Administrative		*	*	*

Figure 1-2.The solid waste management Matrix

Source: Adapted from Ref.10

Four key issues emerge from the above discussion:

1. The Solid waste management Matrix

The advantage of the solid waste management matrix of scales and themes is its essential simplicity - allowing for easy understanding and its adoption to various scales, and socio-political and cultural situations. Gaps in existing solid waste management programmes and initiatives can also be identified. The matrix helps in understanding the interrelationships and interconnectedness of the various issues involved.

2. End-of-Pipe v/s Life-Cycle

There is a gradual shift from 'end-of pipe' solutions that focus on waste disposal, to a source based approach that is aimed at 'life-cycle' analysis. This places the responsibility not only on households, but also in manufacturers and retail businesses. Greater awareness at the local and community level has forced businesses and industries to take a more environmentally friendly approach to their activities, including better management of solid wastes that they produce, using a more holistic life-cycle assessment (LCA is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle.).

3. Commercial Government Partnership

As a consequence of the above two points is the realization that collection and processing of waste is not the exclusive domain of the local government - calling for a more comprehensive partnership between the community and local governments where each actor has a role to play towards waste minimization, waste recycling and waste disposal.

4. Solid Waste Management and the Larger Urban Environment

As mentioned above, solid waste management is not an isolated, municipal problem that has to be 'done' by the local government. There is a need for a more comprehensive package of measures. Critical to this approach is to integrate solid waste management activities within the larger process of urban environmental management.

1.7. Review questions

1. What is sustainable integrated solid waste management?
2. Why have solid waste management practices been so slow in developing? Will changes come more quickly in the future? Explain
3. Explain Policy and Programme Matrix on Solid Waste Management.
4. Identify and discuss briefly the issues that you feel will be important in the field of solid waste management in the 21 century
5. Describe risks and problems related with solid wastes

CHAPTER TWO

SOURCES, TYPES AND COMPOSITION OF SOLID WASTES

2.1. Learning objectives

By the end of this chapter, the students will be able to:-

1. describe sources of solid waste
2. explain types of solid waste.
3. describe the advantages of determining the composition of solid wastes
4. explain future changes in components of solid wastes.

2.2. Introduction

Knowledge of the sources and types of solid wastes, along with data on the composition and rates of generation, is basic to the design and operation of the functional elements associated with the management of solid wastes. The materials that are collected under the term solid waste include many different substances from a multitude of sources. The sources of solid wastes are dependent on the socioeconomic and technological levels of a society.

- ❖ A small rural community may have known types of solid wastes from known sources (i.e. the wastes are more homogenous). Wastes from industrial and mining areas are also more homogenous.
- ❖ Urban communities (metropolitan cities) have many sources (The wastes are more heterogeneous).

2.3: Sources and Types of solid Wastes

There are different sources and types of solid wastes as shown in Table 2-1

Table 2-1: Sources and Types of solid Wastes

S.No	Source	Typical waste generators	Types of solid wastes
1	Residential	Single and multifamily dwellings	Food wastes, Paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g. Bulky items, consumer electronics, white goods, batteries, oil tires), and household hazardous wastes.
2	Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, and special wastes.
3	Commercial	Stores, hotels, restaurants, markets, office buildings, etc	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
4	Institutional	Schools, hospitals, prisons, government centers	Same as commercial
5	Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, Steel, concrete, dirt, etc.
6	Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment	Industrial process wastes, scrap materials, off- specification products, slag tailings
7	Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off- specification products, slag, tailings
All of the above should be included as" municipal solid waste."			
	Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g. pesticides)

Sourec: Adapted in part from Ref.6

Definition of some types of solid wastes

- **Refuse**: It is a general name given to all wastes except liquid waste. It includes all putrescible (decompose rapidly by bacteria) and non putrescible (non decomposable) wastes.

- **Garbage**: Putrescible wastes resulting from the growing, handling, processing, cooking and consumption of food. E.g. Vegetables, fruits, bones, bread, injera etc.
  - High quantities of garbage are generated during the summer months, when vegetable wastes are more abundant.
  - The increased use of processed and packaged foods has reduced garbage production and increased the combustible rubbish.It requires careful handling with frequent removal and adequate disposal. Why?
- **Rubbish:** represents all non-putrescible wastes except ash.

There are two categories of rubbish:

A. **Combustible;** - organic in nature and includes items such as paper, cardboard, wood yard clippings, bedding, plastics etc.

B. **Non-combustible:** - are inorganic materials, which include metals, glass, ceramics, and other minerals.

- **Ashes:** an incombustible material that remains after a fuel or solid waste has been burnt.
- **Infectious wastes**: are wastes that contain or carry pathogenic organisms in part or in whole such as wastes from hospitals and biological laboratories soiled with blood or bodily fluids
- **Special wastes:** are wastes from residential and commercial sources that includes.
  - Bulky items (large worn out or broken household, commercial, and industrial items like, Furniture, lamps, bookcases, filing cabinets, etc.)
  - Consumer electronics (includes worn-out, broken, and other no- longer wanted items such as radios, stereos, TV sets.
  - White goods (large worn – out a broken household, commercial, and industrial appliances such as stoves, refrigerators, dishwashers, clothes washers and dryers)

- **Organic waste:** Food waste, paper, cardboard, plastics, textiles, rubber, leather, wood, yard wastes.
- **Inorganic waste**: Glass, crockery (cups, plates, etc) tin cans, aluminum, and other metals.
- **Dead bodies**: dead animals like dogs ,cows, donkey etc.

2.4 Composition of solid wastes and their determination

Composition is the term used to describe the individual components that make up the solid waste stream and their relative distribution, usually by percent by weight. Information on the composition of solid waste is important in evaluating equipment needs, systems and management programs and plans.

Table 2-2. Typical distribution of components in residential municipal solid waste for different countries (in % of total)

Components	Low-income	Middle-income	Upper income
Organic			
• Food waste	40-85	20-65	6-30
• Paper	1-10	8-30	20-45
• Cardboard	—	—	5-15
• Plastics	1-5	2-6	2-8
• Textiles	1-5	2-10	2-6
• Rubber	—	—	0-2
• Leather	—	—	0-2
• Yard Wastes	1-5	1-10	10-20
• wood	—	—	1-4
Inorganic			
• Glass	5	5	8
• Aluminum	2	2	0
• Dirt, ash etc	20	15	5

Source: Adapted in part from Ref.6

A/Physical composition of solid wastes

Knowing the characteristics the physical component of a community solid waste is important for the following purposes:

A, for the selection and operation of equipment and facilities

B, to assess the possibility for resource of energy recovery

C, to design and analyze disposal facilities

Ways for physical composition Analysis

Individual component study

- Analyze the components of municipal solid waste by type
- Sorting and separation of each and every component is necessary
- Samples each of the heterogeneous refuse of municipal solid waste
- Should be representative (at all seasons of the year)
- Statistical produces (representative ness and randomization)

The types (components) of municipal solid waste may be different from country to country by season, economic condition, developmental level, etc

Table2-3: typical variation observed in the collected composition of residential municipal solid waste

Waste	Percent by weight		Percent variation	
	Winter season	Summer season	Decrease	Increase
Food waste	11.1	13.5		21.6
Paper	45.2	40.0	11.5	
Plastics	9.1	8.2	9.9	
Other organics	4.0	4.6		15.0
Yard wastes	18.7	24.0		28.3
Glass	3.5	2.5	28.6	
Metals	4.1	3.1	24.4	
Inert and other wastes	4.3	4.1	4.7	
	100.0	100.0		

Source: Adapted in part from Ref.6

The individual component study involves to achieve the present composition of solid waste by volume and by weight. Volume measurements although difficult to measure are essential to disposal methods.E.g. to calculate incinerator sizes and land fill areas and to limit hauling capacity of refuse tracks, etc

Moisture content

The moisture content of solid waste is usually expressed in one of two ways

1. In the wet – weight method of measurement: the moisture in a sample is expressed as a percentage of the wet weight of material
2. Dry-weight method, it is expressed as a %age of the dry weight of the material.

Wet- weight Moisture content is expressed as follows

$$M = \frac{w - d}{w} x100$$

Where: M= wet- weight moisture content, %

w= initial mass of sample as delivered, kg

d= mass of sample after drying, kg

Table 2- 4: Typical data on moisture content of municipal solid waste

Component	Moisture Content % by weight	
	Range	Typical
Food wastes	50 -80	70
Paper	4 – 10	6
Card board	4 – 8	5
Plastics	1 – 4	2
Textiles	6 – 15	10
Rubber	1 – 4	2
Leather	8 – 12	10
Garden trimmings	30 - 80	60
Wood	15 - 40	20
Misc. organics	10 - 60	25
Glass	1 – 4	2
Tin cans	2 – 4	3
Nonferrous metals	2 – 4	2
Ferous metals	2 – 6	3
Dirt, ashes, brick, etc	6 – 12	8
MSW	15 - 40	20

Source: Adapted in part from Ref.6

- To obtain the dry weight, the solid waste material is dried in an oven at 77^{o}C (170 ^{0}F) for 24 hours. This temperature and time is used to dehydrate the material completely and to limit the vaporization of volatile materials.
- For most industrial solid wastes, the moisture content will vary from 10 – 35 percent.
- The moisture content of municipal solid waste vary depending on
    1. Composition of the waste
    2. The season of the year
    3. Humidity
    4. Weather condition esp. rain

Examples

1) Estimate the overall moisture content of a sample of MSW as collected, with the typical composition given in table 2-6

Solution

1. Step up a computation table to determine the dry weight of the solid waste components using the data in table 2-7 (based on 100 kg. of as delivered sample).

No	Component	% by weight	Moisture content (%)	Dry weight kg
1	Food wastes	9.0	70	2.7
2	Paper	34.0	6	32
3	card board	6.0	5	5.7
4	Plastics	7.0	2	6.9
5	Textiles	2.0	10	1.8
6	Rubber	0.5	2	0.5
7	Leather	0.5	10	0.4
8	Yard wastes	18.5	60	7.4
9	Wood	2.0	20	1.6
10	Glass	8.0	2	7.8
11	Tin cans	6.0	3	5.8
12	Aluminum	0.5	2	0.5
13	Other metals	3.0	3	2.9
14	Dirt, ash, etc	3.0	8	2.8
	Total	**100**		**78.8**

The dry weight of solid waste components can be determined using the following relation ship.

Dry weight in kg = 100 – moisture content X % as delivered weight of 100kg.

E.g. For food waste = 100 – 70 = 30

9/100x30 =2.7

2. Determine the moisture content using the equation.

$$M = \frac{w-d}{w} x100$$

$$M = \frac{100-78.8}{100} x100 = 21.2\%$$

Example 2: - Estimate the moisture content of a solid waste sample with the following composition based on 100 kg of Sample

Component	% By weight
Food wastes	15
Paper	45
Card board	10
Plastics	10
Garden trimmings	10
Wood	5
Tin cans	5
Total	100

Step- 1 set up a computation table to determine the dry mass of the solid-waste sample using the given data.

Component	% By weight	M.C (%)	Dry weight (kg)
Food waste	15	70	4.5
Paper	45	6	42.3
Card board	10	5	9.5
Plastics	10	2	9.8
Garden trimmings	10	60	4.0
Wood	5	20	4.0
Tin cans	5	3	4.9
Total	100		79.0

Step -2) Determine the moisture content using the equation

$$M = \frac{w-d}{w} x100$$ And data from step-1

$$M = \frac{100-79}{100} x100 = 21.0\%$$

Assignment: Estimate the moisture content for a waste sample with the following composition:

Component	% By weight
Food waste	12
Paper	40
Card board	8
Plastic	4
Garden training	15
Wood	5
Inert (misc.)	16

Density

Under physical composition of solid wastes density is one of the important parameters. Density is defined as the weight of the material per unit volume. The interest in knowing density of solid waste is to assess the total mass and volume of waste that must be managed. The densities of solid waste vary markedly with:

1. Geographic location
2. Season of the year
3. Length of time in storage

Great care should be taken in selecting typical weight or density values. The densities of municipal solid wastes as delivered in compaction vehicles have been found to vary from 178 to 415 Kg/m^3; a typical value is 297 kg/m^3.

B/Chemical composition

Information on the chemical composition of solid wastes is important in evaluating alternative processing and recovery options. For example, the feasibility of combustion depends on the chemical composition of solid waste. If solid wastes are to be used as fuel, the four most important properties to be known are:

1) **Proximate analysis:** Proximate analysis for combustible components of municipal solid waste includes the following tests

a) Moisture (loss of moisture when heated to 105 ^{0}c for 1h)

b) Volatile combustible matter (additional loss of weight on ignition at 950 ^{0}c in a covered crucible)

c) Fixed carbon (combustible residue left after volatile matter is removed)

d) Ash (weight of residue after combustion in an open crucible)

2) **Fusing point of ash:** is defined as the temperature at which the ash resulting from the burning of waste will form a solid (clinker) by fusion and agglomeration. Typical fusion temperature for the formation of clinker from solid waste ranges from 1100 to 1200^{o}c.

3) **Ultimate analysis:** the ultimate analysis of a waste component typically involves the determination of the percent of C (carbon), H (hydrogen) O (oxygen), N (nitrogen), S (sulfur) and ash. The results of the ultimate analysis are used to characterize the chemical composition of the organic matter in municipal solid waste.

Table 2- 5: Typical data on ultimate analysis of the combustible components in municipal solid waste Percent by weight (dry basis)

Component	C	H	O	N	S	Ash
Food waste	48.0	6.4	37.6	2.6	0.4	5.0
Paper	43.5	6.0	44.0	0.3	0.2	6.0
Card board	44.0	5.9	44.6	0.3	0.2	5.0
Plastic	60.0	7.2	22.8	-	-	10.0
Textiles	55.0	6.6	31.2	4.6	0.15	2.5
Rubber	78.0	10.0	-	2.0	-	10.0
Leather	60.0	8.0	11.6	10.0	0.4	10.0
Garden trimmings	47.8	6.0	38.0	3.4	0.3	4.5
Wood	49.5	6.0	42.7	0.2	0.1	1.5
Misc organics	48.5	6.5	37.5	2.2	0.3	5.0
Dirt, ashes, brick, etc	26.3	3.0	2.0	0.5	0.2	68.0

Source: Adapted in part from Ref.6

4) **Energy content:** the energy content of the organic components in municipal solid waste can be determined;

- By using a full scale boiler as a calorimeter
- By using a laboratory bomb calorimeter
- By calculation if the elemental composition is known.

Energy values as discarded basis may be converted to a dry basis by using:

$$\frac{KJ}{Kg}(dry\ basis) = \frac{KJ}{Kg}(as\ discarded)\left(\frac{100}{100 - \%\ moisture}\right)$$

The corresponding equation for a dry ash-free basis is:

$$\frac{KJ}{Kg}(dry\ ashfree\ basis) = \frac{KJ}{Kg}(as\ discarded)\left(\frac{100}{100 - \%\ moisture - \%\ ash}\right)$$

Table 2- 6: Typical data on inert residue and energy content of municipal solid wastes

Component	Inert residue (after complete combustion.) %		Energy, KJ/kg (as discarded basis)	
	Range	Typical	Range	Typical
Food wastes	2-8	5	3,5000-7,000	4,650
Paper	4-8	6	11,600-18,600	16,750
Cardboard	3-6	5	13,950-17,450	16,300
Plastics	6-20	10	27,900 –37,200	32,600
Textiles	2-4	2.5	15,100 –18,600	17,450
Rubber	8 - 20	10	20,900 – 27,900	23, 250
Leather	8 – 20	10	15,100 –19,800	17,450
Garden trimmings	2 -6	4.5	2,300 – 18,600	6,500
Wood	0.6-2	1.5	17,450-19,800	18,600
Misc. organics	2-8	6	11,000- 26,000	18,000
Glass	96-99	98	100 - 250	150
Tin cans	96-99	98	250 – 1,200	700
Non–ferrous metals	90–99	96	-	-
Ferrous metals	94 – 99	98	250 – 1,200	700
Dirt, ashes, bricks, etc	60 - 80	70	2,300 – 11, 650	7,000
MSW	-	-	9,300 – 12, 800	10,500

Source: Adapted in part from Ref.6

Example:
Estimate the energy content of a solid waste sample with the composition given in example2.

SOLUTION

Step -1) set up a computation table to determine the total as discarded energy content of the solid waste sample using the data in table 9.

Component	Percent by weight	Energy KJ/Kg	Total energy, KJ (Based on 100-Kg sample)
Food waste	15	4,650	69,750
Paper	45	16,750	753,750
Card board	10	16,300	163,000
Plastics	10	32,600	326,000
Garden trimmings	10	6,500	65,000
Wood	5	18,600	93,000
Tin cans	5	700	3,500
Total	100		1,474,000

Step 2) Compute the unit energy content

$$\text{Energy content} = \frac{1{,}474{,}000\ \text{KJ}}{100Kg} = 14{,}740\ \text{KJ/kg}$$

Step 3) Determine the energy content on a dry basis

a) Moisture content is 21.0 percent (as calculated)

b) The energy content on dry basis is :

$$\frac{KJ}{Kg}(dry\ \ basis) = 14{,}740\frac{KJ}{Kg}\left(\frac{100}{100-21.0}\right) = 18658$$

Step 4) Determine the energy content on an ash –free dry basis

a) Assume the ash content is equal to 5%

$$\frac{KJ}{Kg}(dry\ ashfree\ basis) = 14{,}740\ \frac{KJ}{Kg}\left(\frac{100}{100-21.0-5}\right) = 19919$$

If energy values are not available, approximate energy values for the individual waste material can be determined by using the equation known as "modified Dulong formula & the data on tables-6, and 8

$$\frac{KJ}{Kg} = 337C + 1428\left(H_2 - \frac{1}{8}O_2\right) + 93S + 23N \text{.............Dulong equation}$$

Where – C = carbon, in percent by weight

H = Hydrogen in percent by weight

O = Oxygen in percent by weight

S = Sulfur in percent by weight

N = Nitrogen percent by weight

C/Biological properties of MSW

The most important biological characteristic of the organic fraction of municipal solid waste is that almost all of the organic components can be converted biologically to gases and relatively inert organic and inorganic solids

Sampling procedures

To assess the total mix of waste components such as those listed in table 2.1, the **load -count** and **mass –volume** methods of analysis are recommended.

The following technique is recommended where it is desired to assess the individual components within a waste category

1. Unload a truckload of wastes in a controlled area away from other operations
2. Divide the waste load into four
3. Select one of the quarters and quarter that quarter
4. Select one of the quartered quarters and separate all of the individual components of the waste into pre-selected components
5. Place the separated components in a container of known volume and measure the volume and mass of each component. The separated components should be compacted tightly to simulate the conditions in the storage containers from which they were collected.
6. Determine the percentage distribution of each component by mass and as- discarded density.
   - Typically from 100 –200 kg (200-400 lb) of waste should be sorted to obtain a representative sample.
   - To obtain a more representative distribution of components, samples should be collected during each season of the year.

Future Changes in Waste Components

In planning for future waste management systems, it will be important to consider the changes that may occur in the composition of solid waste with time. Four waste components that have an important influence on the composition of the wastes collected are food waste, paper and cardboard, yard waste, and plastics.

Food wastes. The quantity of residential food wastes collected has changed significantly over the years as a result of technical advances and changes in public attitude. Two technological advances that have had a significant effect are the development of the food processing and packaging industry and the use of kitchen food waste grinders. The percentage of food waste, by weight, has decreased from about 14 percent in the early 1960s to about 9 percent in 1992.

Recently, because the public has become more environmentally aware and concerned, a trend has developed toward the use of more raw, rather than processed, vegetables. While it would increase the quantity of food wastes collected no firm data are available on this subject.

Paper and cardboard. The percentage of paper and cardboard found in solid wastes has increased greatly over the past half century, rising from about 20 percent in the early 1940s to about 40 percent in 1992. It is expected that use of paper and cardboard will remain stable for the next few year.

Yard wastes. The percentage of yard wastes in municipal solid waste has also increased significantly during the past quarter century, due primarily to passage of laws that prohibit burning of yard wastes. By weight, yard waste currently accounts for about 16 to 24 percent of the waste stream. Environmental conditions such as droughts have also affected the quantities of yard waste collected in certain location.

2.6. Review Questions

1. What are the major sources of solid waste?
2. Mention types solid wastes?
3. Waste composition is the basis of all subsequent waste management programs. Do you feel that the changes in the composition of solid wastes will be significant in next 25? Explain.
4. Describe the advantages of determining the composition of solid wastes

CHAPTER THREE

SOLID WASTE GENERATION

3.1. Learning objectives

By the end of this chapter, the students will be able to

1. describe the functional elements of solid waste management program.
2. list the importance of waste quantities
3. identify methods used to quantify solid waste quantities
4. determine waste generation rates.
5. identify factors that affect waste generation rates

3.2 Introduction

The problem associated with the management of solid wastes in today's society are complex because of the quantity and diverse nature of the wastes, the development of sprawling urban areas, the funding limitations for public services in many large cities, the impacts of technology, and the emerging limitations in both energy and raw materials. As a consequence, if solid waste management is to be accomplished in an efficient and orderly manner, the fundamental aspects and relationships involved must be identified, adjusted for uniformity of data, and understood clearly.

Aesthetic, land use, health, water pollution, air pollution, and economic considerations make proper solid waste storage, collection and disposal of solid wastes municipal and individual functions that must be taken seriously. Indiscriminate dumping of solid waste and failure of the collection system in a populated community would soon cause many health problems. Odors, flies, rats, roaches, crickets, wandering dogs and cats, and fires would dispel and remaining doubts of the importance of proper solid waste storage, collection and disposal.

In this lecture note, the activities associated with the management of solid wastes from the point of generation to final disposal have been grouped into six functional elements.

3.3.Functional elements of solid waste management program

The activities involved with the management of solid wastes from the point of generation to final disposal have been grouped into six functional elements: **1)** Waste generation: **2)** On-site handling, storage, and processing: **3)** Collection: **4)** Transfer and transport: **5)** Processing and recovery: and **(6)** Disposal.

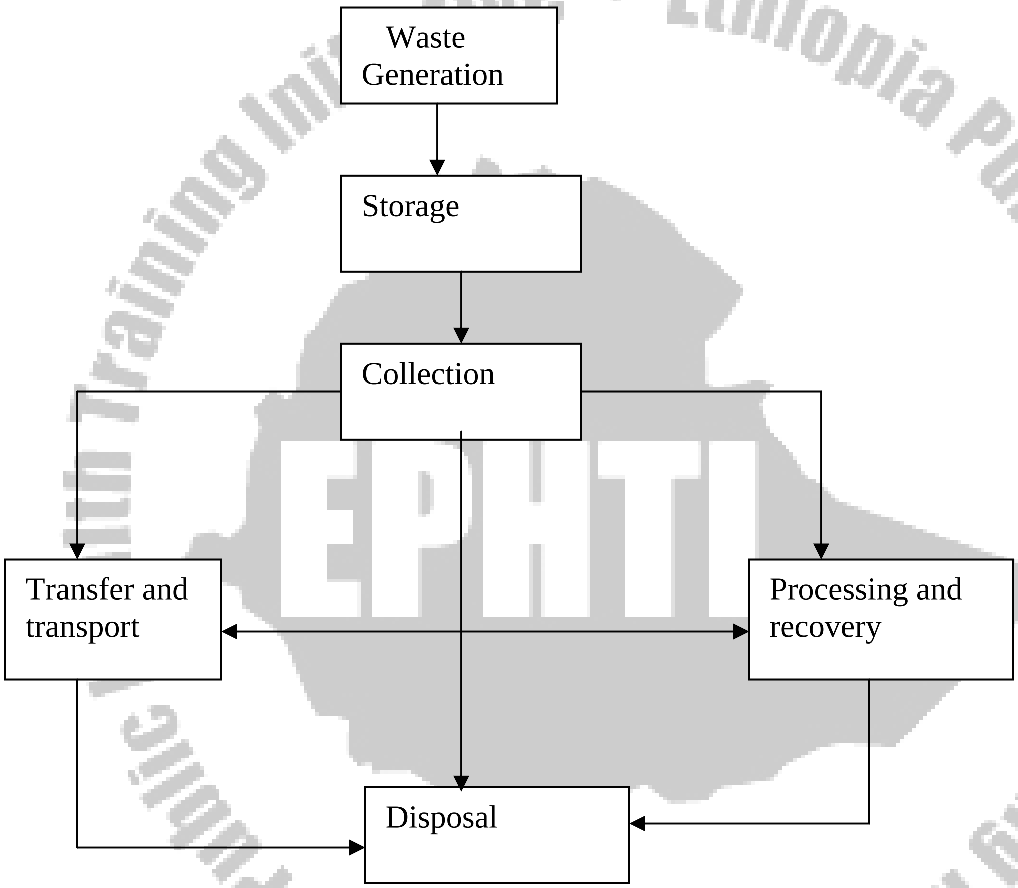


Figure 3-1: Interrelationship of functional elements comprising a solid waste management System

Source: Adapted from Ref.6

By considering each functional element separately it is possible to identify the fundamental aspects and relationships involved in each element and to develop where possible, quantifiable relationships for the purposes of making engineering comparisons analyses, and evaluations.

Table 3-1: Description of the functional elements of solid waste managements.

Functional element	Description
Waste generation	Those activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal
On- site handling, Storage, and processing	Those activities associated with the handling, storage, and processing of solid wastes at or near the point of generation
Collection	Those activities associated with the gathering of solid wastes and the hauling of wastes after collection to the location where the collection vehicle is emptied.
Transfer and transport	Those activates associated with (1) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and (2) the subsequent transport of the wastes, usually over long distance to the disposal site.
Processing and recovery	Those techniques equipment and facilities used both to improve the efficiency of the other functional elements and to recover usable materials, conversion products, or energy from solid wastes.
Disposal	Those activities associated with ultimate disposal of solid wastes including those wastes collected and transported directly to a landfill site, semisolid wastes (sludge) from wastewater treatment plants incinerator residue compost, or other substances from the wires solid waste processing plants that are of no further use.

3.4 Solid Waste Generation

Waste generation encompasses activities in which materials are identified as no longer being of value and are either thrown away or gathered together for disposal. For example, the warping of a candy bar is usually considered to be of little further value to the owner once the candy is consumed and more often that not it is just thrown away, especially outdoors. It is important in waste generation to note that there is an identification step and that this step varies with each individual waste.

Knowledge of the quantities of solid wastes generated, separated for recycling, and collected for further processing or disposal is of fundamental importance to all aspects of solid waste management.

Expression of unit generation

In addition to knowing the source and composition of solid waste, it is equally important to have uniform units of expression. For example, universally accepted units for:

- Household waste (kg/capita/day)
- Commercial waste (kg/x/day where x can be m2 of floor area of commercial establishment, unit volume or dollar in sales, the number of employees, etc.)
- Institutional waste (kg/x/day where x can be the number of students, m2 of the area of park or public place, number of visitors, etc.)
- Market waste (kg/x/day where x can be the number of market lots, m2 of floor area, dollar in sales, etc.)
- Industrial waste (kg/x/day where x can be unit volume or dollar of production output, m^2 of floor area, the number of employees, etc.)
- street sweeping waste (kg/km/day)
- drain cleaning waste (kg/km/day)
- total waste (kg/capita/day)

Methods used to estimate Waste Quantities

Waste quantities are usually estimated on the basis of data gathered by conducting a waste characterization study, using previous waste generation data or some combination of the two approaches.

Methods commonly used to assess solid waste quantities are

1. load-count analysis,
2. weight-volume analysis, and
3. Materials-balance analysis.

In this discussion, it will be helpful to remember that most measurements of waste quantities do not accurately represent what they are reported or assumed to represent. For example, in predicting residential waste generation rates, the measured rate seldom reflects the true rate because there are confounding factors (e.g., onsite storage and the use of alternative disposal location) that make the true rate difficult to assess.

Load-Count Analysis. In this method, the number of individual loads and the corresponding waste characteristics (types of waste, estimate volume) are noted over a specified time period. If scales are available, weight data are also recorded. Unit generation rates are determined by using the field data and where necessary, published data.

Weight-Volume Analysis. Although the use of detailed weight- volume data obtained by weighing and measuring each load will certainly provide better information on the specific weight of the various forms of solid wastes at a given location, the question remains: What information is needed in terms of study objectives?

Materials Mass Balancer Analysis. The only way to determine the generation and movement of solid wastes with any degree of reliability is to perform a detailed materials balance analysis for each generation source, such as an individual home or a commercial or industrial activity. In some cases, the materials balance method of analysis will be required to obtain the data needed to verify compliance with state-mandated recycling programs.

Preparation of Materials Mass Balances. The approach to be followed in the preparation of a material mass balance analysis is as follows.

- First, draw a system boundary around the unit to be studied. The proper selection of the system boundary is important because, in many situations, it will be possible to simplify the mass balance computations.
- Second, identify all the activities that cross or occur within the boundary and affect the generation of wastes.
- Third, identify the rate of waste generation associated with each of these activities.
- Fourth, using appropriate mathematical relationships, determine the distribution is about 40 to 50 percent rubbish (concrete, asphalt, bricks, blocks, and dirt,) 20 to 30 percent wood and related products (pallets stumps, branches, forming and framing lumber, treated shingles), and 20 to 30 percent miscellaneous wastes (painted or contaminated lumber, metals tar-based products, plaster, glass, white goods, asbestos and other insulation material, and plumbing, heating and electrical parts).

Solid Waste Generation Rates

Solid waste generation rates estimate the amount of waste created by residences or businesses over a certain amount of time (day, year, etc.). Waste generation includes all materials discarded, whether or not they are later recycled or disposed in a landfill. Waste generation rates for residential and commercial activities can be used to estimate the impact of new developments on the local waste stream. They may be useful in providing a general level of information for planning purposes

Variation in Generation Rates

The quantities of solid waste generated vary daily, weekly, monthly and seasonally. Information on the variations to be expected in the peak Residential waste g eneration rate usually peak during Christmas holiday season and during spring house cleaning days. In many communities, unlimited collection service is provided on designated clean-up days. In general, as the size of the waste source increases (e.g. from individual residences to a community) the variation in the peak day, week and month decreases.

3.5 Factors that affect waste generation rates.

The effect of source reduction and recycling activities, Public attitudes and legislation, and geographic and physical factors on the generation of solid waste are considered in the following discussion.

1. Effect of source reduction and Recycling Activities on waste Generation.

The effects of source reduction and the extent of recycling activities on waste generation are considered in the following discussion:

Source Reduction: Waste reduction may occur through the design, manufacture, and packaging of products with minimum toxic content, minimum volume of material, and /or a longer useful life. Waste reduction may also occur at the household, commercial or industrial facility through selective buying patterns and the reuse of products and materials. Because source reduction is not a major element waste reduction at the present time, it is difficult to estimate the actual impact that source reduction programs have had (or will have) on the total quantity of waste generated. Nevertheless, source reduction will likely become an important factor in reducing the quantity of waste generated in the future. For example, if the postage rate for bulk mail were increased significantly, the quantity of bulk mail would be reduced sharply. Some of the other ways in which source reduction can be achieved follow:

- ❖ Decrease unnecessary or excessive packaging
- ❖ Develop and use products with greater durability and repairability (e.g., more durable appliances and tires)
- ❖ Substitute reusable products for disposable, single-use products (e.g., reusable plates and cutlery, refillable beverage containers, cloth diapers and towels)

- Use fewer resources (e.g., two-sided copying)
- Increase the recycled materials content of products
- Develop rate structures that encourage generators to produce less waste.

Extent of Recycling: The existence of recycling programs within a community definitely affects the quantities of wastes collected for further processing or disposal.

2. Effect of public Attitudes and legislation on waste Generation.

Along with source reduction and recycling programs, public attitudes and legislation also significantly affect the quantities generated.

Public Attitudes Ultimately, significant reduction in the quantities of solid wastes generated occur when and if people are willing to change –of their own volition- their habits and lifestyles to conserve natural resources and to reduce the economic burdens associated with the management of solid wastes. A program of continuing education is essential in bringing about a change in public attitudes.

Legislation Perhaps the most important factor affecting the generation of certain type of wastes is the existence of local, state, and federal regulations concerning the use of specific materials. Legislation dealing with packaging and beverage container materials is an example. Encouraging the purchase and use of recycled materials by allowing a price differential (typically 5 to 10 percent) for recycled materials is another method.

3. Effect of Geographic and physical factors on waste Generation

Geographic and physical factors that affect the quantities of waste generated and collected include location, season of the year, the use of kitchen waste food grinders, waste collection frequency, and the characteristics of the service area . Because broad generalizations are of little or no value, the impact of these factors must be evaluated separately in each situation.

Geographic location. Different climates influence both the amount of certain type of solid wastes generated and the time period over which the wastes are generated. For example, substantial variations in the amount of yard and garden wastes generated in various parts of the country are related to climates are related to climates. That is, in the warmer southern areas, where the growing season is considerably longer than in the northern areas, yard wasters are collected not only in considerably greater amounts but also over a longer time. Because of the variations in the quantities of certain types of solid wastes generated under different climates, special studies should be conducted when such information will have a significant impact on the system. Often, the necessary information can be obtained from a load-count analysis.

Season of the year. The quantities of certain types of solid wastes are also affected by the season of the year. For example, the quantities of food waste related to the growing season for vegetables and fruits, seasonal sampling also will be required to assess changes in the percentage distribution of the waste materials comprising municipal solid waste , especially in areas of the country with extensive vegetation.

Use of Kitchen Food Waste Grinders. While the use of kitchen food waste grinders definitely reduces the quantity of kitchen wastes collected, whether they affect quantities of wastes generated is not clear, because the use of home grinders varies widely throughout the country, the effects of their use must be evaluated separately in each situation if such information is warranted. Unit waste allowances made in the field of waste water treatment for estimating the additional suspended solids capita contributed from homes with food grinders varies from 0.1 to 0.04 Kg/capita. Typically, the clues used in the waste water field only reflect the increase in solids removed at wastewater treatment facilities and do not reflect the material that has solublized in the process of being transported. More realistic values for estimating the effect of food waste grinders are 0.04 to 0.05 Kg/capita. Alternatively, for homes with food waste grinders one can assume that 25 to 33 percent of the total amount of food waste generated is ground up.

Frequency of collection. In general, where unlimited collection service is provided, more wastes are collected. This observation should not be used to infer that more wastes are generated. For example, if a homeowner is limited to one or two containers per week, he or she may, because of limited container capacity, store newspapers or other materials; with unlimited service, the homeowner would tend to throw them away. In this situation the quantity of wastes generated may actually be the same, but the quantity collected is considerably different. Thus, the fundamental question of the effect of collection frequency on waste generation remains unanswered.

Characteristics of Service Area. Peculiarities of the service area can influence the quantity of solid wastes generated. For example, the quantities of yard wastes generated on a per capita basis are considerably greater in many of the wealthier neighborhoods than in other parts of town. Other factors that will affect the amount of yard waste include the size of the lot, the degree of landscaping, and the frequency of yard maintenance.

3.6 Review Questions

1. What is the importance of knowing solid waste quantities?
2. What are methods used to quantify solid waste quantities?
3. How can you determine waste generation rates?
4. One of the first steps in conducting a solid waste management study is the identification of factors contributing to the generation of solid wastes now and in the future. List the factors that affect the generation of municipal, industrial, and agricultural solid wastes in your community. Explain those that may affect generation in the future.

CHAPTER FOUR

SOLID WASTE HANDLING, STORAGE AND PROCESSING AT THE SOURCE

4.1. Learning objectives

By the end of this chapter, the students will be able to

1. discuss the importance of onsite handling of solid waste
2. explain onsite solid waste handling methods
3. list types of containers that can be used to store solid waste
4. describe the objectives of on-site solid waste processing

4.2 Introduction

The handling, storage and processing of solid wastes at the source before they are collected is the second of the six functional elements in the sold waste management system. Because this element can have a significant effect on the characteristics of the waste, on subsequent functional elements, on public health and on public attitudes concerning the operation of the waste management system, it is important to understand what this element involves. This chapter includes a description and discussion of the handling, storage, and processing of waste materials at the source.

4.3 On-site handling

On- site handling methods and principles involve public attitude, individual belief and ultimately affects the public health. It is an activity associated with the handling of solid waste until they are placed in the containers used for their storage before collection. This may take place at any time before, during or after storage.

Importance of on- site handling of solid waste

- reduce volume of waste generated
- alter physical form
- recover usable materials

On- site handling Methods

- sorting
- shredding
- grinding
- composting

4.4. On- site Storage

The first phase to manage solid waste is at home level. It requires facilities for temporarily storing of refuse on the premises. Individual house holder or business man has responsibility for onsite storage of solid waste.

For individual homes, industries, and other commercial centers proper onsite storage of solid waste is the beginning of disposal. Because unkept or simple dumps are sources of nuisance, flies, smells and other hazards.

There are four factors that should be considered in the on-site storage of solid waste. These are the type of container to be used, the location where the containers to be kept, public health, the collection method and time.

1. Storage container

Garbage and refuse generated in kitchens and other work areas should be collected and stored in properly designed and constructed water-proof garbage cans (waste bins). The cans or receptacles can be constructed from galvanized iron sheet or plastic materials. They should have tightly fitting covers. They must be of such size that, when full, can be lifted easily by one man. They should be located in a cool place over platforms, at least 30 centimeters above ground level. After putting in garbage, they should be kept covered. The bins must be emptied at least daily and maintained in clean conditions. A typical example of garbage can, constructed from galvanized iron sheet, dimensions: diameter 45 cm and height 75 cm, is shown in Figure 4-1 below.

An adequate number of suitable containers should be provided with proper plat forms with receptacles stand. The number may depend on the amount, type and establishments where the need arise. Suitable containers shall be water tight, rust resistant, tight fitting covers, fire resistant, enough size, light in weight, side handle and washable.

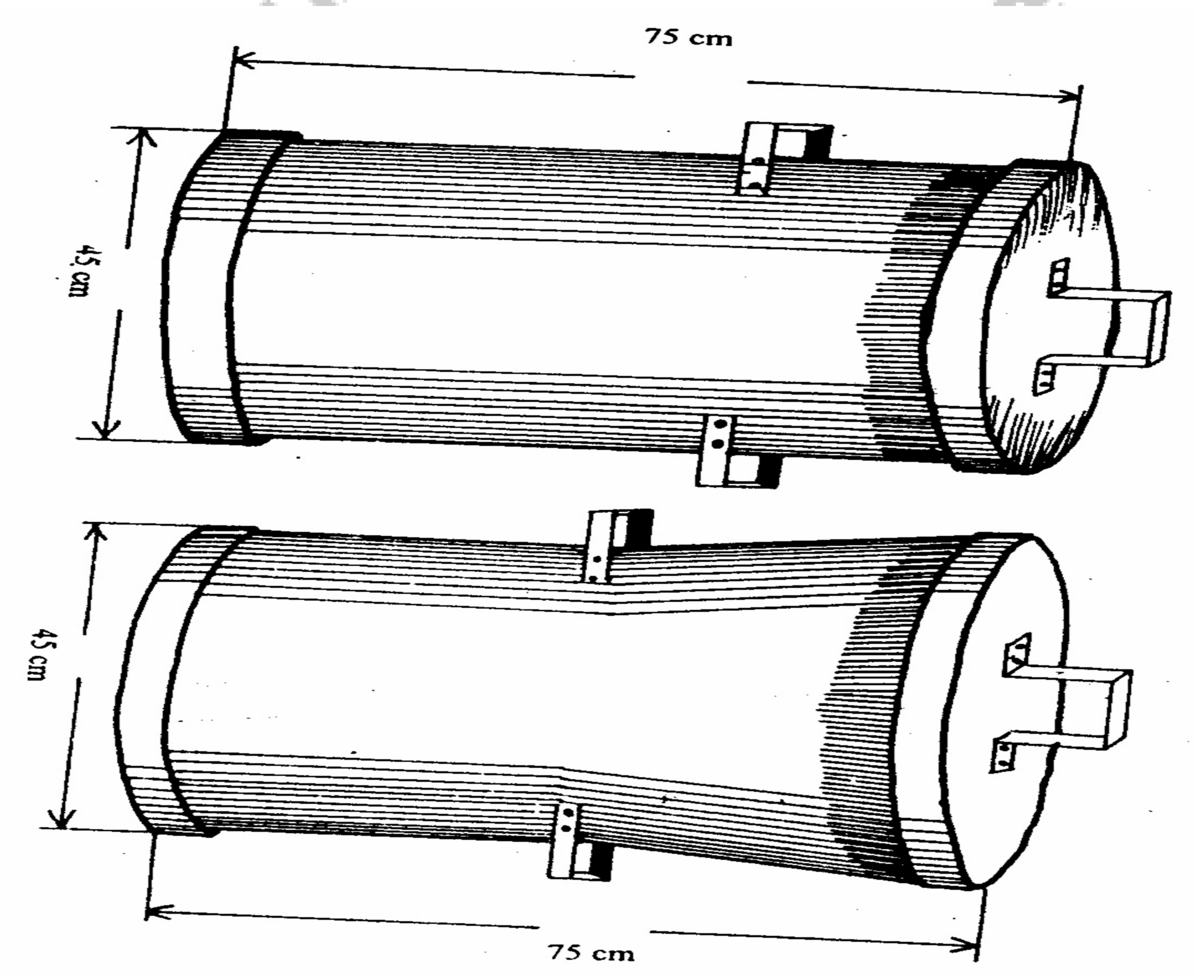


Figure 4-1. Typical Garbage Can with Tightly Fitting Cover

Source: Gabre-Emanuel Teka (1997): Solid waste disposal from food premise; In Food Hygiene

2. Container size (capacity)

Consideration should be given for the size of the loaded container that must be hauled the collection vehicle or to the disposal site.

Therefore, container size for:-

- ash up to 80 to 128 litter
- mixed refuse should not exceed 120 to 128 litter
- rubbish up to 200 liter
- office waste is 10-20 liter
- kitchen waste is 40 liter
- garbage is 48 to 80 liter

Plastic liners for cans and wrapping for garbage reduce the need for cleaning of cans and bulk containers, keep down odors, rat and fly breeding

Galvanized metal is preferable for garbage storage because it is resistant to corrosion. Plastic cans are light in weight but are easily gnawed by rats.

Bulk containers are recommended where large volumes of refuse are generated, such as at hotels, restaurants, apartment houses, shopping centers.

A concrete plat form provided with a drain to an approved sewer with a water faucet at the site to facilitate cleaning.

4.5 On- site processing

On-site processing is intended to improve disposal options, recover valuable resources, and prepare materials for recovery as new products or energy. Obviously an engineer would want to evaluate various processing options for the system's impact on the local and global environment, reliability, safety to workers and the local community, ease of operation, efficiency, economics, and, aesthetics (noise, odors, litter, increased traffic).

Some of the objectives of solid waste processing include:

1) Component separation (hand sorting, screening, magnetic separation, air classification for lighter materials such as paper and plastic). Remember though, as stated earlier, it is much more efficient to separate wastes at the source.

2) Volume reduction (baling, shredding, incineration). Incineration may reduce volume by more than 90%. However, engineers should realize that incineration is not a popular option by many local communities. However, a community may be more acceptable to unpopular alternatives such as incineration if they are combined with an aggressive source reduction/recycling program that eliminates the potential production of hazardous air emissions, and the risk associated with these emissions is equally shared between wealthy and poor residents.

3) Size reduction (Shredding, grinding)

4) Resource recovery (composting, energy recovery, material recovery)

A number of processing technologies have been developed for solid waste management and one of the jobs of the engineer is to select and design the most sustainable and cost effective for a given community. And of course, the engineer needs to listen to the input of local residents. It should be noted that a lot of good ideas for solid waste processing have proven to be inadequate when built to full-scale.

4.6. Review questions

1. What is the importance of onsite handling of solid waste?
2. Mention onsite solid waste handling methods?
3. List types of containers that can be used to store solid waste
4. Explain the objectives of on-site solid waste processing

CHAPTER FIVE

COLLECTION METHODS

5.1. Learning objectives

By the end of this chapter, the students will be able to

1. explain types of collection services
2. describe types of collection equipment
3. mention two types of routing system
4. discuss about the organization of solid waste collection program

5.2 Introduction

This is the removal of refuse from collection points to final disposal site. It is the most expensive part of solid waste management as compared with other operation and management procedures, because it demands special vehicles, experienced people to manage, more manpower, hand tools, and more funds for fuel, salary, maintenance. It includes gathering or picking up of solid waste from the various sources, taking the collected wastes to the location where it is emptied, and unloading of the collection vehicle.

Collection cost has been estimated to represent about 50 to 80% of the total cost of solid waste management depending on the type of disposal facility used. In the USA for example, of the money spent for the collection, transportation and disposal of solid waste, approximately 60-80% was spent on collection. This shows that if the collection system or operation is improved there will be significant saving in the overall cost.

Collection program demands the following more than any thing else

- Special vehicles for different types of wastes (logs, garbage, special wastes)
- Experienced people to manage and administer.
- More specialized machineries or simple hand tools and manpower.
- Monetary funds to be used for fuel, salary, maintenance.

The collection operation of solid waste management is considered from four aspects. These are:

- ❖ Understanding the types of collection services that are provided
- ❖ The types of collection system, equipment and labour requirement.
- ❖ An analysis of collection system including component relationship.
- ❖ General methodology involved in setting up collection routes.

5.3 Collection Service

Different types of Collection services are given to residential, commercial and industrial areas. Collection services for Residential areas depend up on the type of dwelling (low rise, detached, attached, high rise apartment etc.) The most common types of Residential Collection services include the following.

1. Curb

In this system the homeowner is responsible for placing the containers to be emptied at the curb (road side) on collection day and for returning the empty containers back to his house.

2. Alleys

This is collection of waste from the alley ways beside houses. Who will take the containers to the collection vehicles could be arranged between the owner of the house and the collection crew (the organization).

3. Set-out

Waste containers are set out from the homeowner's property by additional collection crews that go with the collection vehicle. The owner of the house is responsible for returning the empty containers to their storage location.

4. Backyard/setout set-back

Collection crew that goes with the collection vehicle are responsible for bringing out stored solid waste form the dwelling units and other activities related to collection. It is the only satisfactory system in which the house holder does not get involved.

Table 5-1: Comparison of Residential collection services

Considerations	Type of Services			
	Curb	Alley	Set out	Back yard
1. Requires home owners cooperation				
• Carry container	Yes	Optional	Non	No
• Carry empty container	Yes	Optional	Yes	No
2. Require schedule service for home owner cooperation	Yes	No	Yes	No
3. Spillage and litter problem	High	High	High	Low
4. Containers visible	Yes	No	Yes	No
5. Attractive to scavengers	Yes	Highest	No	No
6. Prone to upsets	Yes	Yes	Yes	No
7. Average crew required	1- 4	1-3	1-5	3-5
8. Crew time	Low	Low	Medium	High
9. Crew injury rate	Low	Low	Medium	High
10. Cost of crew and time	Low	Low	Medium	Medium

Source: Adapted from Ref.6

Frequency of collection.

The frequency of collection depend on the quantity of solid waste, time of year, socioeconomic status of the area served, and municipal or contractor responsibility. In business districts refuse, including garbage from hotels and restaurants should be collected daily except on Sundays.

In residential areas, twice-a-week for refuse collection during warm months of the year and once a week at other times should be the maximum permissible interval. Slum areas usually require at least twice-a-week collection. The receptacle should be either emptied directly into the garbage truck or carted away and replaced with a clean container.

Refuse transferred from can to can will cause spilling, which result in pollution of the ground and attraction of flies. If other than curb pickup is provided, the cost of collection will be high. Some property owners are willing to pay for this extra service. Bulky wastes should be collected every 3 months.

Garbage - should be collected at least two times weekly in residential sections in summer and winter, however, most commercial establishments should be accorded daily collection service through out the year.

Dead body: should be collected immediately

Rubbish - is generally collected weekly in residential areas and daily in business sections.
Mixed refuse - should be collected twice daily from most commercial concerns.

The provision of frequent collection services is important in the prevention of fly breeding in garbage. Because irregular collections can contribute to the nuisances and hazards which result under poor storage conditions and in chances the amount greater than the expected requirement from house holders.

Methods of Loading the Solid waste to Vehicles

The method of loading of solid waste on to the vehicles is usually accomplished in many different ways. This also depends on the economy, organization and technological level of the society. Nevertheless, the methods used are:

- ❖ Direct lifting and carrying of loaded containers to the collection vehicle for emptying
- ❖ Rolling loaded containers on their rims or rollers to the collection vehicle
- ❖ Use of small lifts for rolling loaded containers to the collection vehicle
- ❖ Use of large container into which waste from small containers are emptied and finally lifted by mechanical means.

5.4 Types of Collection Systems

Solid waste collection systems may be classified from several points of view. These are:

1. Mode of operation
2. Equipment use
3. Type of waste collected

1. Mode of operation

Solid waste collection systems are classified according to their operation in to two categories. These are:

- **Hauled container system :** which is a system where the containers used for storage of wastes are hauled to the disposal site, emptied and returned. This system is ideally suited for the removal of wastes from sources where generation rate is high.

There are three main types of hauled container systems:

1. Hoist truck system
2. Tilt-frame container system
3. Trash-trailer system

- **Stationary container system** : where the containers used for the storage of waste remain at the point of generation, except for occasional short trip to the collection vehicle.

There are two main types Stationary Container Systems

1. Mechanically loaded systems
2. Manually loaded systems

2. Equipment used

- Some of the equipments used are containers, machineries, hand tools etc. Containers for hauled systems or operation have various sizes and shapes. Basically, since the system is used to haul wastes from sources where the route of generation is high large containers are provided. **Hauled containers system** requires only one track, and one driver, to accomplish the collection cycle. But each container picked up must be returned back requiring a round trip travel.

- ❖ Therefore, when using this system:
  - o Container size and utilization are of great economic advantages.
  - o Compressing waste to haul long distance has good advantage.

3. Type of waste collected

The collection of solid waste is not a single process. There are at least five different phases. Namely:

Phase one: Generated waste in the premises (house, industry etc) to dust bin

Phase two: From temporary storage (dust bin) to collection track

Phase three: Truck moves from house to house or collection center to collection center

Phase four: Collected waste to disposal site or transfer station

Phase five: Waste sorted for resource recovery or other management.

The individual home owner must transfer what ever he considered waste to the refuse can or bin which may be located inside or outside the house. The owner or collection crew moves the waste to the collection truck. The truck must collect waste from many homes in the most efficient and economical way possible. Collected waste may be taken to a transfer station where large volume will be collected and transported using bigger transport means (train, large compactor truck, chains of tractor wagons) or the waste will be sorted for possible resource recovery or recycling program. Finally, what is supposed to be disposed will be taken to a disposal site.

Analysis of Collection System

To establish labor and vehicle requirement for the various collection systems and methods, the unit time required to perform each task must be determined. By separating the collection activities into unit operations, it is possible to:

- ❖ Develop design data and relationship that can be used universally
- ❖ Evaluate both the variables associated with collection activities and the variables related to, or controlled by, the particular locations.

Before the relationships for collection systems can be modeled effectively the component task must be explained. On the basis of previous or known activities involved in the collection of solid waste there are four unit operations that need to be defined. These unit operations are:

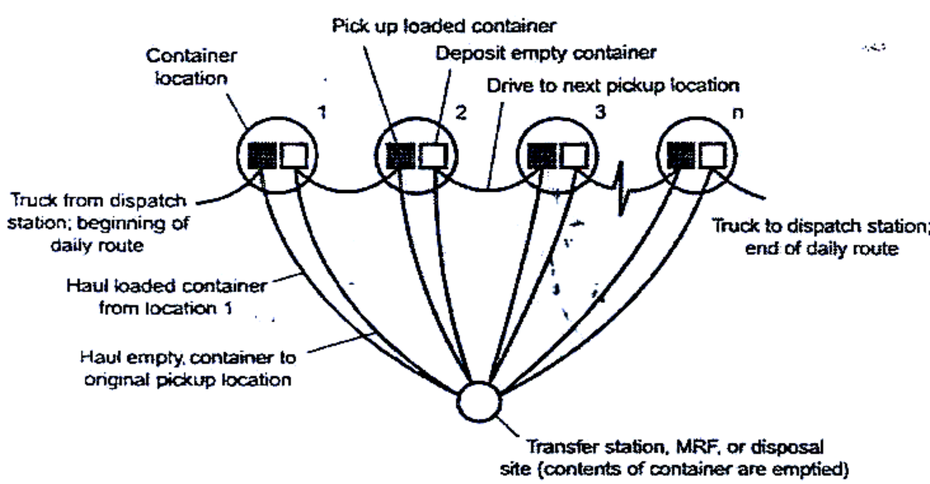
1. Pick-up
2. Haul
3. At-site
4. Off-route/site

1. Pick up

1.1. Pick-up as related to hauled container system operated in the CONVENTIONAL MODE refers to the:

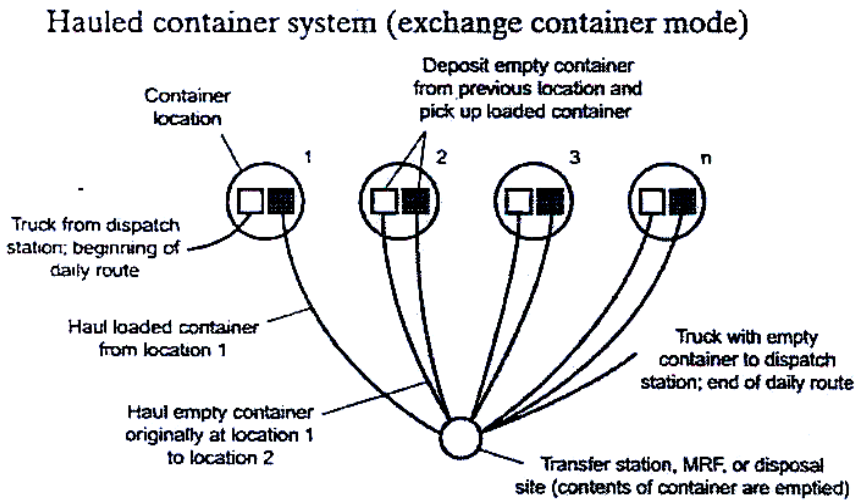
- ❖ Time Spent driving to the next container after an empty container has been deposited.
- ❖ time spent picking up the loaded container
- ❖ time required to re-deposit the container

figure Hauled container system (conventional mode)



1.2. Pick-up as related to the exchange container mode refers to the:

- ❖ Time required to pick-up a loaded container and to deposit a container at the next location after its content have been emptied.



1.3. Pick-up for stationary container system refers to:

A. The time spent loading the collection vehicle beginning with the stopping of the vehicle prior to loading the content of the first container and ending when the content of the last container to be emptied have been loaded.

2. Haul

For hauled container system:-

Hauling solid waste represent the time required to reach the disposal site starting after a container whose content are to be emptied has been loaded on the truck, plus the time spent after living the disposal site until the truck arrives at the location where the empty container is to be deposited. However, it does not include time spent at disposal.

For stationary container system:

❖ The time required to reach the disposal site starting after the last container on the route has been emptied, or the collection vehicle is filled, plus the time after leaving the disposal site until the truck arrives at the location the first container to be emptied on the next collection route.

3. At site

This refers to the time spent at the disposal site and includes the time spent waiting to load as well as the time spent unloading.

4. Off- Route

This include the time spent on activities that are non productive from the point of view of the overall collection system or operation. Many of the activities associated with off-rout time are either necessary or unnecessary.

a. necessary time is:

- Time spent checking in and out in the morning and at the end of the day
- Time lost due to unavoidable congestion
- Time spent on equipment repair (tire, engine etc).

b. unnecessary time includes:

- Time spent for lunch in excess of the time allowed
- Time spent on an unauthorized break
- Time spent with friend etc

Mathematical Analysis:

Solid waste collection needs a lot of thinking and statistical and mathematical data to base the program. The following formulae are examples.

1. Haul container system

The time required per trip, which also corresponds to the time required per container, is equal to the sum of:

- The pick up
- At site
- And haul times

T_{HCS}= P_{hcs} + s+ h

Where T_{hcs}= Time per trip for hauled container system, h/trip

$P_{hcs=}$ pick up time per trip for hauled container system, h/trip

s = at site time/trip

h= Haul time/trip

- For hauled container system Pick up and at site are relatively constant, but the haul time depends on speed and distance
- From experience haul time may be approximated by:

h = a+ bx

Where:

h = Total haul time, h/trip

a. = Empirical constant h/trip

b. Empirical constant h/mi

x. = Round trip head distance mi/trip

Therefore: - T_{hcs} = P_{hcs} + s + a + bx

And the pick-up time for haul container system (P_{HCS}) per trip for the haul container system is:

P_{hcs} = pc + uc + dbc

Where: P_{hcs} = pick-up time per trip

pc = time required to pick up loaded container

uc = time required to unload empty container

dbc = time required to drive between container location

Note: If average time required between containers is unknown use equation h = a + bx.

The number of trips that can be made per vehicle per day with a hauled container system can be determined by:

Nd = [H (1-W) – (t_1+t_2)]/T_{hcs}

Where: Nd = No of trips per day

H = Length of work day h/day

W=: Off-route factor, expressed as a fraction

t_1=time required to drive from dispatch station to the first container location.

t_2=time to drive from the last container location to the dispatch station.

T_{hcs}= Time per trip for hauled container system, h/trip

Note: (1-w) = off route factor varies from 0.10 – 0.25. Factor of 0.15 is representative for most operation.

The number of trips required per day can be estimated by the following expression:

$$N_d = \frac{v_d}{cf}$$

Where: N_d= Number of trips per day

V_d = daily waste generation yd^3 per day

c = Average container size, yd^3/trip

f = Weighed average container utilization factor. (The container utilization factor is the fraction of the container volume occupied by solid waste. Because this factor will vary with the size of the container, a weighed container utilization factor should be used.

Example 1:

The following average speeds were obtained for various round trip distances to a disposal site. Find the haul speed constants (a, and b) and round trip haul time for a site that is located 11.0 miles away.

Round trip distance (x, mi/trip)	average haul speed (y, mi/h)	Total time (h=x/y, h)
2	17	0.12
5	28	0.18
8	32	0.25
12	36	0.33
16	40	0.40
20	42	0.48
25	45	0.56

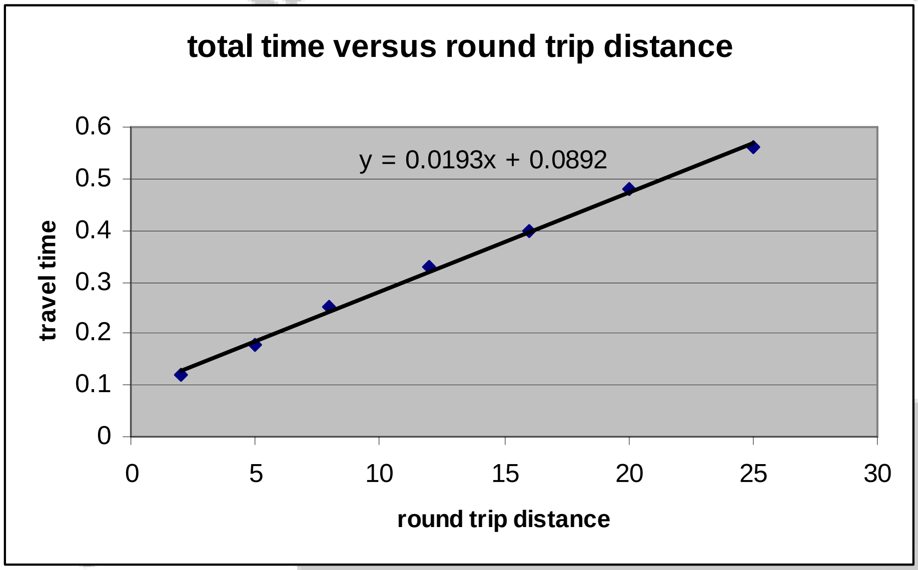
1. The basic haul speed equation is:

$$y = \frac{x}{a + bx}$$

❖ Linearized form of equation is:

$$\frac{x}{y} = h = a + bx$$

2. Plotting $\frac{x}{y}$ which is the travel time versus the round trip distance x.



3. Determine the constants a, and b using the plot graph.

Constant a = 0.080

b = 0.020

4. Find the round –trip haul time for a site that is 11.0 miles away.

Round trip distance = 11.0 X 2 = 22 mi/trip

Haul time h= a+ bx

= 0.080 + (0.020X22)

= 0.52 h/trip

Example 2: Analysis of hauled container system

Solid waste is to be collected from a new industrial area using large containers. Based on the traffic studies, the average time to drive from the garage to the first container location and from the last container location to the garage each day will be 15 and 20 min, respectively. The time required to pick up the loaded container and to deposit empty container is about 0.4 h/trip. Collection vehicles spent an average of 10 min, to unload the containers at the disposal site. The average time required to drive between containers is 6 min and the one way distance to the disposal site is 15.5 mi. determine the number of containers that can be emptied per day based on an 8 hours workday? Assume the off-route factor, W, is equal to 0.15, and haul speed constants (a, and b) as 0.016 and 0.018 h/trip respectively.

Solution:

1. determine the pickup time per trip

   P_{hcs} = pc + uc + dbc

   Pc + uc = 0.4 h/trip (given)

   dbc = 0.1 h/trip (given)

   P_{hcs} = 0.4 h/trip + 0.1 h/trip = 0.5 h/trip

2. determine the time per trip

   $T_{hcs} = P_{hcs} + s + a + bx$

   s = 0.1 h/trip

   a. = 0.016 h/trip

   b. 0.018 h/mi

   x. = 2 x 15.5 = 31 mi/trip

   T_{hcs} = 0.5+ 0.16 + 0.016+ 0.018 (31) = 1.23 h/trip

3. determine the number of trips that can be made per day

$N_d = [H (1-W) – (t_1+t_2)]/T_{hcs}$

$H = 8$ h/day (given)

$W = 0.15$ (given)

$t_1 = 0.25$ h (given)

$t_2 = 0.33$ h (given)

$T_{hcs} = 1.23$ h/trip

$N_d = [8(1-0.15) – (0.25+0.33)]/1.23] = 5.05$ trips/day

2. Stationary Container System

(For mechanically loaded vehicle)

For system using self loading collection vehicles, the time per trip could be found out using the following equation.

$T_{scs} = (P_{scs} + s + a + bx)$

Where T_{scs}= Time per trip for stationary container system, h/trip

$P_{scs.}$ = pick up time per trip for stationary container system, h/trip

s. = at site time/trip

a. =Empirical constant h/trip

b. =Empirical constant h/mi

x. =Round trip haul distance mi/trip

For stationary container system, the pickup time is given by:

$P_{scs} = C_t\,(uc) + (n_p – 1)\,(dbc)$

Where: P_{scs} = pickup time per trip of stationary container system

C_t = No. of containers emptied per trip

Uc = Average unloading time per container

n_p = No. of containers per pick up location per trip

dbc= average time spent driving between container locations ..h/container

The number of containers that can be emptied per collection trip is related directly to the volume of the collection vehicle and the compaction ratio that can be achieved. Thus:

$$C_t = \frac{vr}{cf}$$

Where C_t = No. of containers emptied per trip

v = volume of collection vehicle yd^3/trip

r = compaction ratio yd^3/container

c = container volume

f = weighed average container utilization factor

The number of trips required per day can be estimated by using:

$$N_d = \frac{V_d}{vr}$$

Where: N_d = No. of collection trip per day

V_d= daily waste generation

v = volume of collection vehicle yd^3/trip

r = compaction ratio yd^3/container

Developing collection routes

Detailed route configurations and collection schedules should be developed for the selected collection system. Efficient routing and rerouting of solid waste collection vehicles can decrease costs by reducing the labor expended for collection. Routing procedures usually consist of two separate components. These are micro routing and macro routing.

Macro routing, also referred to as route balancing, consists of dividing the total collection area into routes sized so they represent one day's collection for one crew. The size of each route depends on the amount of waste collected per stop, distance between stops, loading time, and traffic conditions. Barriers, such as railroad embankments, rivers, and roads with heavy competing traffic, can be used to divide route territories. As much as possible, the size and shape of route areas should be balanced within the limits imposed by such barriers.

For large areas, macro routing can be best accomplished by first dividing the total area into districts, each consisting of the complete area to be serviced by all crews on a given day. Then, each district can be divided into routes for individual crews.

Using the results of the macro routing analysis, micro routing can define the specific path that each crew and collection vehicle will take each collection day. Results of micro routing analyses can then be used to readjust macro routing decisions. Micro routing analyses should also include input and review by experienced collection drivers.

Micro routing analyses and planning can do the following:

- increase the likelihood that all streets will be serviced equally and consistently
- help supervisors locate crews quickly because they know specific routes that will be taken
- provide theoretically optimal routes that can be tested against driver judgment and experience to provide the best actual routes.

The method selected for micro routing must be simple enough to use for route rebalancing when system changes occur or to respond to seasonal variations in waste generation rates. For example, growth in parts of a community might necessitate overtime on several routes to complete them. Rebalancing can perhaps consolidate this need for increased service to a new route. Also, seasonal fluctuations in waste generation can be accommodated by providing fewer, larger routes during low-generation periods (typically winter) and increasing the number of routes during high-generation periods (typically spring and fall).

Routing collection vehicle is a very difficult problem. "In 1736 the brilliant mathematician Leonard Ever was challenged when asked to design a route for a parade across the seven bridges of a city in Eastern Prussia such that the parade would not cross the same bridge twice but would end at the starting point. It was found to be difficult to do it outright".

Heuristic Route Development: A Manual Approach

The heuristic route development process is a relatively simple manual (i.e., not computer-assisted) approach that applies specific routing patterns to block con- figurations. United States Environmental Protection Agency (USEPA) developed the method to promote efficient routing layout and to minimize the number of turns and dead space encountered

When using this approach, route planners can use tracing paper over a fairly large-scale block map. The map should show collection service garage locations, disposal or transfer sites, one-way streets, natural barriers, and areas of heavy traffic flow. Routes should then be traced onto the tracing paper using the rules presented below

Rules for Heuristic Routing

1. Routes should not be fragmented or overlapping. Each route should be compact, consisting of street segments clustered in the same geographical area.
2. Total collection plus hauling times should be reasonably constant for each route in the community (equalized workloads).
3. The collection route should be started as close to the garage or motor pool as possible, taking into account heavily traveled and one-way streets .
4. Heavily traveled streets should not be collected during rush hours.
5. In the case of one-way streets, it is best to start the route near the upper end of the street, working down it through the looping process.
6. Services on dead-end streets can be considered as services on the street segment that they intersect, since they can only be collected by passing down that street segment. To keep left turns at a minimum, collect the dead-end streets when they are to the right of the truck. They must be collected by walking down, backing down, or making a U-turn.
7. Waste on a steep hill should be collected, when practical, on both sides of the street while vehicle is moving downhill. This facilitates safety, ease, and speed of collection. It also lessens wear of vehicle and conserves gas and oil.
8. Higher elevations should be at the start of the route.

9. For collection from one side of the street at a time, it is generally best to route with many clockwise turns around blocks.

Note: Heuristic rules 8 and 9 emphasize the development of a series of clockwise loops in order to minimize left turns, which generally are more difficult and time-consuming than right turns. Especially for right-hand-drive vehicles, right turns are safer.

10. For collection from both sides of the street at the same time, it is generally best to route with long, straight paths across the grid before looping clockwise.
11. For certain block configurations within the route, specific routing patterns should be applied.

Computer-Assisted Routing

Computer programs can be helpful in route design, especially when routes are rebalanced on a periodic basis. Programs can be used to develop detailed micro routes or simpler rebalances of existing routes. To program detailed micro routes, planners require information similar to that needed for heuristic routing. This information might include block configurations, waste generation rates, distance between residences and between routes and disposal or transfer sites, topographical features, and loading times. Communities that already have a geographic information system (GIS) database are in an especially good position to take advantage of computerized route balancing.

Municipalities can also use computers to do simple route rebalancing. For example, the city of Wilmington, Delaware, of USA used a spreadsheet program, average generation rates, and block configuration data to balance the weight of waste collected on each route. The city assumed that loading times were equal in all areas and altered the boundaries of existing routes. Specific collection vehicle paths were left to drivers. As a result of this simple rebalancing, the city was able to reduce its waste collection crew and save collection costs. For smaller communities, rebalancing can be accomplished using manual methods.

Planning of solid waste collection program.

a. Routing system of collection

There are two types of routing system. These are:

1. Micro routing :the routing of a vehicle within its assigned collection zone concerned with how to route a truck through a series of one or two way streets so that the total distance traveled is minimized very difficult to design and execute

2. Macro routing: large scale routing to the disposal site and the establishment of the individual route boundaries.

b. Modes of operation in solid waste collection

1. Hauled container system- the containers used for the storage of wastes are hauled to the disposal site, emptied and returned.
2. Stationary container system - the containers used for the storage of waste remain at the point of generation except for occasional short trip to the collection vehicles.

C. Unit operations

1. Pick-up - refers to the time spent driving to the next container after an empty container has been deposited.
2. Haul - represents the time required to reach the disposal site starting after a container whole contents are to be emptied has been loaded on the truck plus the time spent after leaving the disposal site until the truck arrive at the location where the empty container to be deposited.
3. At site- refers to the time spent at the disposal site and includes the time spent waiting to unload as well as the time spent in a loading.
4. Off-site - includes the time spent on activities that are non-productive from the point of view of the over all collection system.

Organization of solid waste collection program

Many cities and towns require homeowners to use certain types of receptacles. Collectors usually pick up at the curb in front of the dwelling. In some neighborhoods the collectors pick up the receptacles in the backyard, as the people who live there consider receptacles too bulky to handle and unsightly in front of dwelling.

Haul distance to the disposal facility must be taken into consideration in making a cost analysis. In some highly urbanized areas it is economical to reduce haul distance by providing large, specially designed trailers at transfer stations. In sub-urban and rural areas, container stations can be established at central locations. These stations may include a stationary compactor for ordinary refuse and a bin for tires and bulk items. Separate bins for paper, glass, and aluminum may also be provided.

Labor requirement for the collection of solid waste depends on both the type of service provided and the collection system used:-

1. for hauled container system one person, two for safety, driver to drive the vehicle load and unload containers and empty the container at the disposal site.
2. for stationary container system the labor requirement for mechanically loaded ones are essentially the same with hauled container system. Occasionally, a driver and two helpers are used.

For manually loaded systems the number of collectors may vary from one to three depending on the type of service and the type of collection equipment, Curve collection need less persons than back yard collection which may require multi personal crew.

Figure 5-4: Waste containers used in large-volume generator sites.

Source: Adapted from Ref.10

5.5 Review Questions

1. What are types of collection services?
2. What types of solid waste collection equipment do you know?
3. List two types of routing system
4. How can you organize of solid waste collection program in you locality?

CHAPTER SIX

SEPARATION, PROCESSING AND TRANSFORMATION OF SOLID WASTE

6.1. Learning objectives

By the end of this chapter, the students will be able to

1. mention the purpose of solid waste separation
2. explain solid waste processing methods
3. explain key concepts in municipal solid waste processing
4. describe types of materials recovered from municipal solid wastes
5. discuss solid waste transformation strategies

6.2 Introduction

Environmentally sound management of increasing amounts of difficult-to-treat or organic wastes is among the topics of major concern today in most cities. The logical starting point for solid waste management is to reduce the amounts of waste that must be managed, that is, collected and disposed of as nuisances and hazards. Agenda 21, the agreement reached among participating nations at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, emphasized, in Chapter 21, that reducing wastes and maximizing environmentally sound waste reuse and recycling should be the first steps in waste management. The environmental, social, and economic benefits of integrating practices of waste reduction into municipal solid waste are the bases for an emerging worldwide agenda for solid waste management.

Source separation refers to keeping different categories of recyclables and organics separate at source, i.e., at the point of generation, to facilitate reuse, recycling, and composting.

6.3 Separation and processing of solid wastes

In the affluent countries, the main motivations for waste reduction are frequently related to the high cost and scarcity of sites for landfills, and the environmental degradation caused by toxic materials in the deposited wastes. The same considerations apply to large metropolitan areas in developing countries that are surrounded by other populous jurisdictions. The places that currently do not have significant disposal pressures can still benefit from encouraging waste reduction

Solid waste managers in developing countries tend to pay little attention to the topic of separating and processing of solid wastes because the wastes they collect are between 50% to 90% organics, dirt and ashes. These municipal wastes, however, are amenable to composting or digestion, provided they contain very low levels of synthetic materials.

Key concepts in municipal waste processing

Waste reduction: all means of reducing the amounts of waste that must be collected and disposed of by solid waste authorities. Ranges from legislation and agreements at the national level for packaging and product redesign to local programs to prevent recyclables and compost able organics from entering final waste streams.

Source reduction: any procedure to reduce wastes at the point of generation, in contrast to sorting out recyclable components after they have been mixed together for collection.

The following are all methods of initiating source reduction:

- Do not purchase as much, or reduce use.
- Purchase products with reduced toxics.
- Purchase environmentally preferred products.
- Purchase products with less packaging.
- Purchase concentrated products.
- Purchase products in bulk or larger sizes.

- Buy multiple use products.
- Do not replace for style.
- Purchase more durable products.
- Maintain properly and repair instead of replace.
- Purchase reusable products and then reuse or donate to charity.
- Purchase more efficient products, or use products more efficiently.
- Purchase manufactured product. Borrow, share, or rent product.

Recycling: the process of transforming materials into secondary resources for manufacturing new products.

Redemption center: waste trading enterprise that buys recyclable materials and sells to brokers. Sometimes also called "buy-back center".

Producer responsibility: Producers of products or services accept a degree of responsibility for the wastes that result from the products/services they market, by reducing materials used in production, making repairable/recyclable goods, and/or reducing packaging.

Resource recovery

Resource recovery means the obtaining of some economic benefit from material that someone has regarded as waste. It includes

- **reuse** - being used for the same purpose again (such as refilling a soft drinks bottle);
- **recycling** - processing material so that it can be used again as the same material, such as the processing of waste paper to make pulp and then new paper;
- **conversion** - processing the material to make something different (such as producing padding for clothing and sleeping bags from plastic bottles, or producing compost from food waste)
- **energy recovery -** usually referring to the burning of waste so that the heat can be used (for example, for heating swimming pools). Another method of energy recovery is to collect the gas that is produced in very large sanitary landfills and use it as a fuel or to generate electricity.

Some key factors that affect the potential for resource recovery are the cost of the separated material, its purity, its quantity and its location. The costs of storage and transport are major factors that decide the economic potential for resource recovery. In many low-income countries, the fraction of material that is won for resource recovery is very high, because this work is done in a very labor-intensive way, and for very low incomes. In such situations the creation of employment is the main economic benefit of resource recovery. The situation in industrialized countries is very different, since resource recovery is undertaken by the formal sector, driven by law and a general public concern for the environment, and often at considerable expense.

Composting is an excellent method of recycling biodegradable waste from an ecological point of view. However, many large and small composting schemes have failed because composting is regarded as a disposal process, and not a production process. It is essential - as in any production process - to pay careful attention to the marketing and the quality of the product. Composting should be an activity of the agricultural sector, not the waste management sector. It can be a big mistake to try to impose on low-income countries the methods of recycling that are used in industrialized countries.

Resource recovery is a partial solid waste disposal and reclamation process. It can be expected to achieve about 60% reductions in future land fill volume requirements. Resource recovery must recognize what is worth to recover and the environmental benefits.

Resource recovery is a complex, economical and technical system with social and political implications. All of which require critical analysis and evaluation before a commitment is made. They demand capital cost, operating cost, market value of reclaimed materials and material quality, potential minimum reliable energy sales, assured quantity of solid wastes, continued need for a sanitary landfill for the disposal of excess and remaining unwanted materials and incinerator residue, a site location close to the center of the generators of solid wastes.

Materials Recovered from Municipal solid Wastes

As the amount of material recovered from Municipal solid Wastes continues to increase as communities develop program to meet waste diversion goals, materials specifications will become an important factor. In general, there is less contamination in source separated material, but collection is more labor-intensive, and many communities are choosing to sort all materials at a central materials recovery facility. In many regions, markets for materials are not keeping pace with the volume collected, and it is expected that buyers will tighten specifications; as a result, vendors will no longer have assured markets, and will be competing to sell materials. As the specifications for recovered materials become more restrictive, recovery program managers must consider buyer specifications carefully when choosing collection and sorting systems, especially where large capital expenditure are involved.

Materials that are separated for recycling from municipal solid waste are aluminum, paper, plastics, glass, ferrous metal, nonferrous metal, yard wastes, construction and demolition wastes and tires

1. Aluminum. Aluminum recycling is made up of two sectors: aluminum cans and secondary aluminum. Secondary aluminum includes window frames, storm doors, siding, and gutters. Because secondary materials are of different grades, specifications for recycled aluminum should be checked, to recover the maximum value when selling separated material to brokers. The demand for recycled aluminum cans is high; as it takes 95 percent less energy to produce an aluminum can from an existing can than from one.

2. Paper. The principal types of waste paper that are recycled are old newspaper, cardboard, high- grade paper, and mixed paper. Each of these four grades consists of individual grades, which are defined according to the type of fiber, source, homogeneity, extent of printing, and physical or chemical characteristics, High grade paper includes office paper, reproduction paper, computer print out, and other grades having a high percentage of long fibers. Mixed grades include paper with high ground-wood content, such as magazines; coated paper; and individual grades containing excessive percentages of ‘’ out throws’’ (paper of lower grades than the grade specified).

Paper is the single most frequently seen item in most landfills, taking up more land space. It accounts for more than 40 % of a landfill's contents. Newspapers alone may take up as much as 13 to 30 % of the space in landfills. It is not enough to just change from paper grocery bags to recyclable cloth bags. Paper in landfills not biodegrade; it mummifies.

Paper may be one of the most recyclable waste products. To establish a newsprint recycling mill it takes three to five years and costs from $300 to $500 million to build. Can the capital investment be recouped if there is no community plan to market the recycled paper? If economic incentives were given to Creative entrepreneurs, more products could easily be developed.

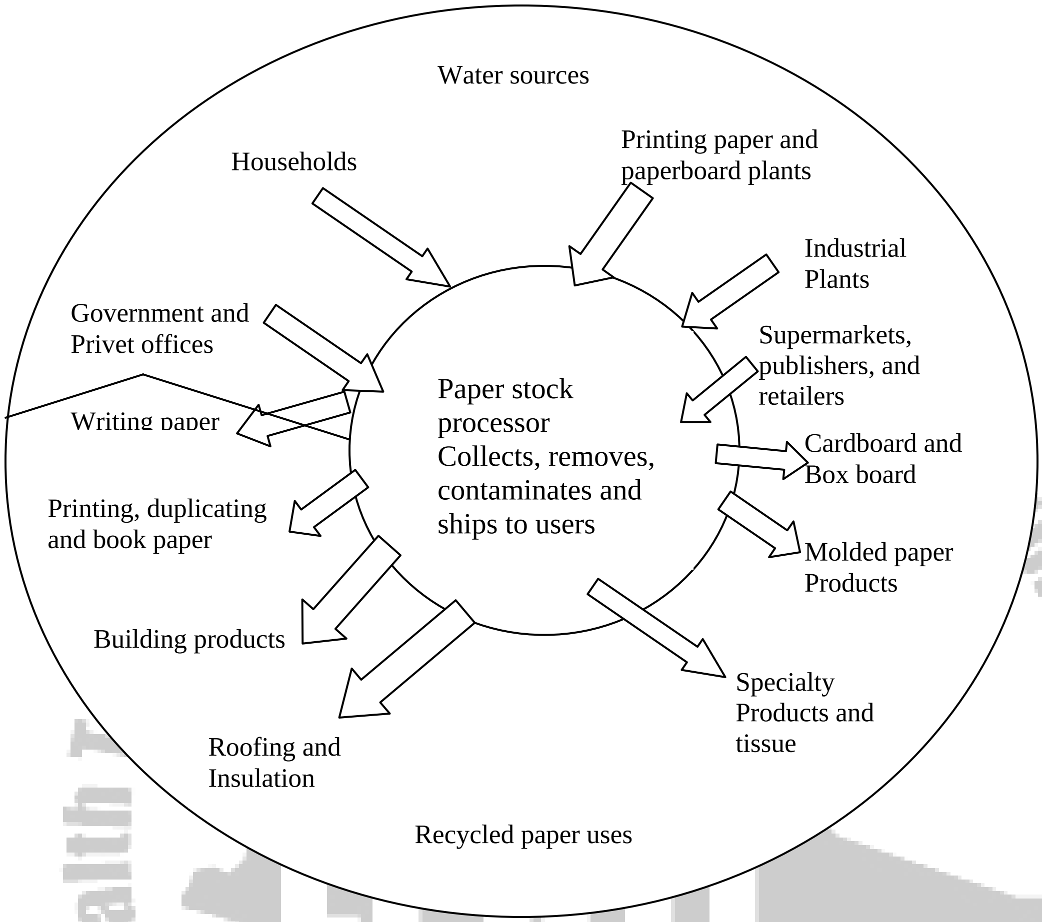


Figure 6-1. The sources and uses of recycled paper.

Source: World Health Organization (1999): Safe Management of wastes from health Care activities.

Table 6-1: Percentage distribution of paper types found in residential solid waste

Type of paper	Percent by weight	
	Range	Typical
Newspaper	10-20	17.7
Books and magazines	5-10	8.7
Commercial printing	4-8	6.4
Office paper	8-12	10.1
Other paperboard	8-12	10.1
Paper packaging	6-10	7.8
Other no packaging paper	6-10	7.8
Tissue paper and towels	8-12	10.6
Corrugated materials	20-25	22.7
Total		100.0

3. Plastics. Plastics can be classified into two general categories: clean commercial grade scrap and post-consumer scrap. The two type of post consumer plastics that are now most commonly recycled are polyethylene terephthalate, which is used for the manufacture of soft drink bottles, and high-density polyethylene used for milk and water containers and detergent bottles. It is anticipated that all of other types of plastics will be recycled in greater quantities in the future, however, as processing technologies improve.

Bacteria and fungi that would usually live on the decaying waste of natural food, fauna, and flora cannot digest these recovery polymers. Instead, toxic cadmium and lead compounds used as binders can leach out of plastics and ooze into groundwater and surface water in unlined or failed landfills. Unfortunately, plastic is one of the most common non-biodegradable wastes deposited in landfills.

There are a number of plastic items that create great decomposition problems, among them are diapers, grocery bags and balloons. Today only 3 percent of all plastic containers are recycled.

Plastic threatens the lives of millions of marine animals who get entangled in plastic netting. Autopsied marine animals have revealed that their intestines were full of non-biodegradable plastic.

Marine mammals and birds have suffocated, strangled, and been poisoned by the plastic waste such as can rings or balloons that has been expelled into the oceans and into the air. Those who fish currently dump around 17,781,120 kg of plastic into the oceans each year. It is thought that as many as a million sea birds and 100,000 marine mammals in just the Northern Pacific Ocean die each year from eating or becoming entangled in plastic waste.

4. Glass. Glass is also a commonly recycled material. Container glass (for food and beverage packing,), flat glass (e.g., window glass), and pressed or amber and green glass are the three principal type of glass found in Municipal solid Wastes. Glass to be reprocessed is often separated by color into categories of clear, green and amber.

5. Ferrous Metals (Iron and Steel). The largest amount of recycled steel has traditionally come from large items such as cars and appliances. Many communities have large scrap metal piles at the local landfill or transfer station. In many cases, the piles are unorganized and different metals are mixed together, making them unattractive to scrap metal buyer. Steel can recycling is also becoming more popular. Steel cans, used as juice, soft drink, and food containers, and easily separated from mixed recyclables or municipal solid waste using large magnets (which also separate other ferrous metals).

6. Nonferrous Metals. Recyclable nonferrous metals are recovered from common household items (outdoor furniture, kitchen cookware and appliances, ladders, tool, hard ware); from construction and demolition projects (copper wire, pipe and plumbing supplies, light fixtures, aluminum siding, gutters and downspouts, doors, windows); and from large consumer, commercial, and industrial products (appliances, automobiles, boats, trucks, aircraft, machinery). Virtually all nonferrous metals can be recycled if they are sorted and free of foreign materials such as plastics, fabrics, and rubber.

7 Yard Wastes Collected Separately. In most communities yard wastes are collected separately. The composting of yard wastes has become of great interest as cities and towns seek to find way in which to achieve mandated diversion goals. Leaves, grass clippings, bush clippings, brush are the most commonly composted yard wastes. Stumps and wood are also compostable, but only after they have been chipped to produce a smaller more uniform size. Composting of the organic fraction of Municipal solid Wastes is also becoming more popular.

8. Construction and Demolition Wastes. In many locations construction and demolition wastes are now being processed to recover marketable items such as wood chips for use as a fuel in biomass combustion facilities, aggregate for concrete in construction projects, ferrous and nonferrous metals for remanufacture, and soil for use as fill material. The reprocessing of construction and demolition wastes is gaining in popularity as disposal fees at landfills continue to increase.

9. Tires

Discarded tires pose two particular vector health threats to a community: rats and mosquitoes. Tires create an excellent breeding place for rats and mosquitoes, which in turn carry diseases to humans.

An automobile tire contains about 10 liters of oil, which has the potential to produce enough electricity to serve a small town. Unfortunately, when tires burn in an uncontrolled environment, they are extremely difficult to contain or extinguish.

There are actually some tire graveyards that have been burning for years. Although 15 million old tires are recycled each year, the number of recycled tires is actually going down each year as new blends of rubber and steel-belted tires cannot use recycled tires.

Techniques involved in resource recovery

1. compaction which mechanically reduce the volume of solid waste
2. chemical volume reduction by incineration
3. mechanical size reduction by shredding, grinding and milling
4. component separation by hand sorting , air separation magnetic separation and screening

Promoting waste reduction and materials recovery at the national and local levels

Action for waste reduction can take place at both national and local levels. At the national level, the main routes to waste reduction are:

- redesign of products or packaging;
- promotion of consumer awareness; and
- promotion of producer responsibility for post-consumer wastes (this applies mostly to industrialized countries).

At the local level, the main means of reducing waste are:

- diversion of materials from the waste stream through source separation and trading;
- recovery of materials from mixed waste;
- pressure on national or regional governments for legislation on redesigning packaging or products; and
- support of composting, either centralized or small-scale.

Sound policy approaches for improved recovery of materials are addressed here within the social and technical realities of developing economies. The specific technologies for recovering particular types of materials (e.g. glass, metals, plastics) are not described. Further, although an understanding of how the markets for recyclables affect waste reduction policies is important for strategic planning there is little use in promoting recovery of materials for which there are uncertain markets.

Building on what is working

As explained below, people in many developing countries already carry out significant waste reduction practices. In designing strategies for further waste reduction, the first principle should be to build on what exists and appears to be working. In general, sound practices for the majority of cities and towns in the developing world rest upon:

- ❖ facilitating the existing private sector (formal and informal) in waste reduction where current practices are acceptable, and ameliorating problems encountered by all the relevant actors through access to capacity-building, financing, and education; and
- ❖ designing such assistance to dovetail with the strategic plan for management municipal solid wastes.

6.4 Transformation of solid waste

Physical, chemical, and biological transformations

physical; 1. component separation
2. mechanical volume reduction (densification)
3. mechanical size reduction

chemical – combustion (chemical oxidn)
- pyrolysis (destructive distillation)
- gasification

biological – aerobic composting
- anaerobic digestion

Figure 6-3 below clearly demonstrate decision area for storage and collection of solid wastes

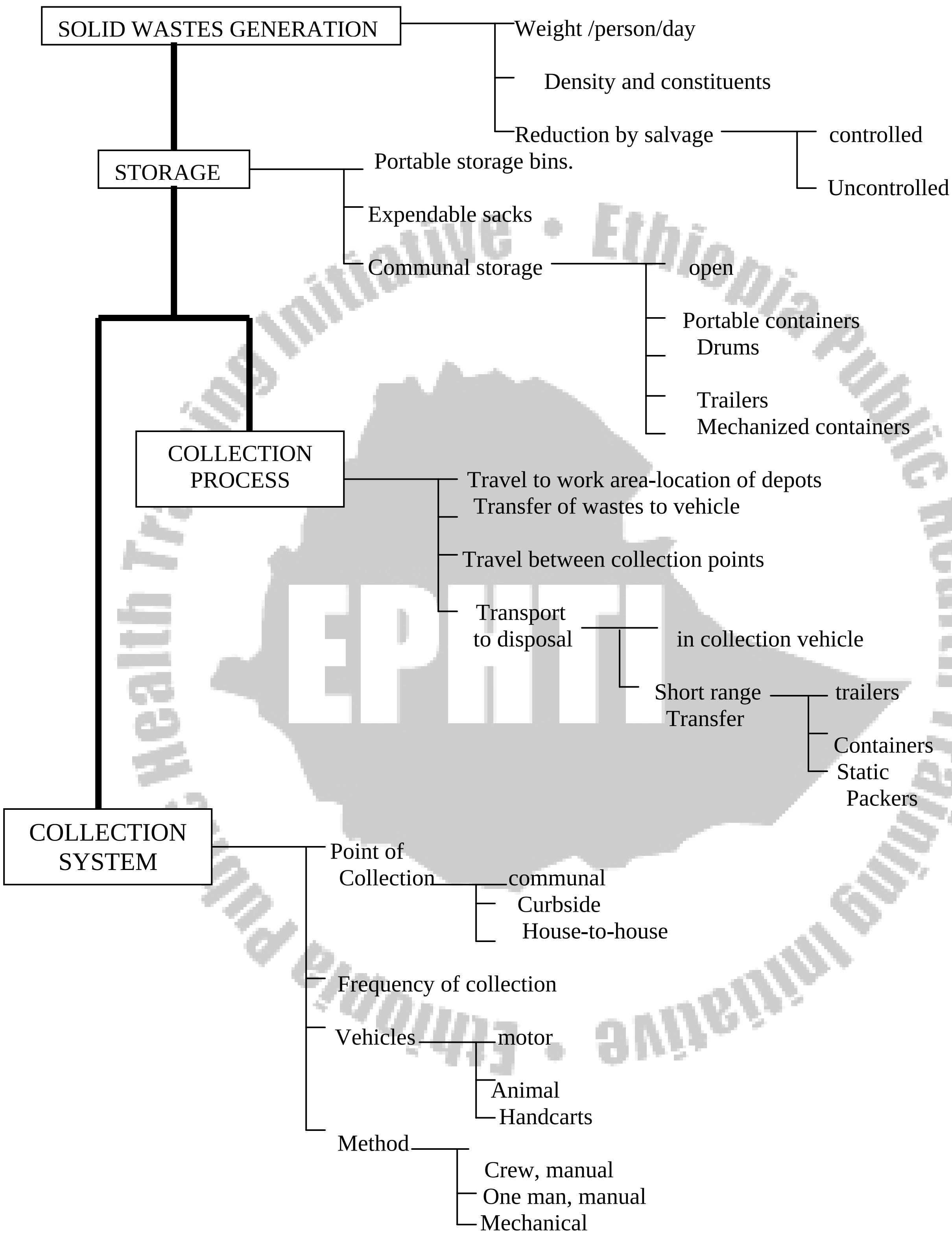


Figure 6-3. Flow chart and decision area for storage and collection
Sourec: Adapted from Ref.10

6.5 Review Questions

1. Mention the purpose of solid waste separation
2. Explain solid waste processing methods
3. Explain key concepts in municipal solid waste processing
4. Discuss solid waste transformation strategies
5. Describe types of materials recovered from municipal solid wastes

CHAPTER SEVEN

TRANSPORT AND TRANSFER OF SOLID WASTES

7.1. Learning objectives

By the end of this chapter, the students will be able to

1. discuss the purpose of transport and transfer stations in the process of solid Wastes management
2. describe factors that should be considered in designing of transfer station and Selection of equipment

7.2. Introduction

In the field of solid waste management, the functional element of transfer and transport refers to the means , facilities , and appurtenances used to effect the transfer of wastes from one location to another, usually more distant ,location. Typically, the contents of relatively small collection vehicles are transferred to larger vehicles that are used to transport the waste over extended distances either material recovery facilities or to disposal sites. Transfer and transport operations are also used in conjunction with material recovery facilities to transport recovered materials to markets or waste- to- energy facilities and to transports residual materials to landfills.

Usually the collection vehicle is also used for the long distance transport of refuse though it is becoming more common to transport refuse to a local “transfer station” where the waste is then transferred to a larger vehicle. Thus, it must be large enough to minimize the number of trips to the processing site, yet small enough to be maneuverable during collection. If the distance to the disposal site is large, then the waste is typically transferred to a larger vehicle such as truck trailer, rail car, or barge.

Transfer stations are used to collect the refuse at a central location and to reload the wastes in to a vehicle where the cost per kilogram-kilometer ton-mile will be less for the movement of the ultimate waste to the disposal site. Transfer stations are employed when the disposal site is situated at significant distance from the point of collection.

A transfer station can reduce the cost of transporting refuse by reducing man power requirement and total kilometers. When a collection vehicle goes directly to the disposal site the entire crew, driver plus laborers are idle. For a transfer vehicle only one driver is needed. As the distance from the centers of solid waste generation increases, the cost of direct haul to a site increases. Ideally, the transfer station should be located at the center of the collection service area.

A transfer station may include stationary compactors, recycling bins, material recovery facility, transfer containers and trailers, transfer packer trailers, or mobile equipment.

A transfer station should be located and designed with drainage of paved areas and adequate water hydrants for maintenance of cleanliness and fire control and other concerns like land scaling, weight scales, traffic, odor, dust, litter, and noise control. Transporting vehicles could be a modern packer truck (trailer), motor-tricycles, animal carts (appropriate for developing countries), hand carts and tractor

Transfer and transport station should provide welfare facilities for workers(lockers, toilets, showers); small stores for brooms, shovels, cleaning materials, lubricants, parking facilities for hand trucks, sweepers , refuse collectors, and office and telephone for the district inspector.

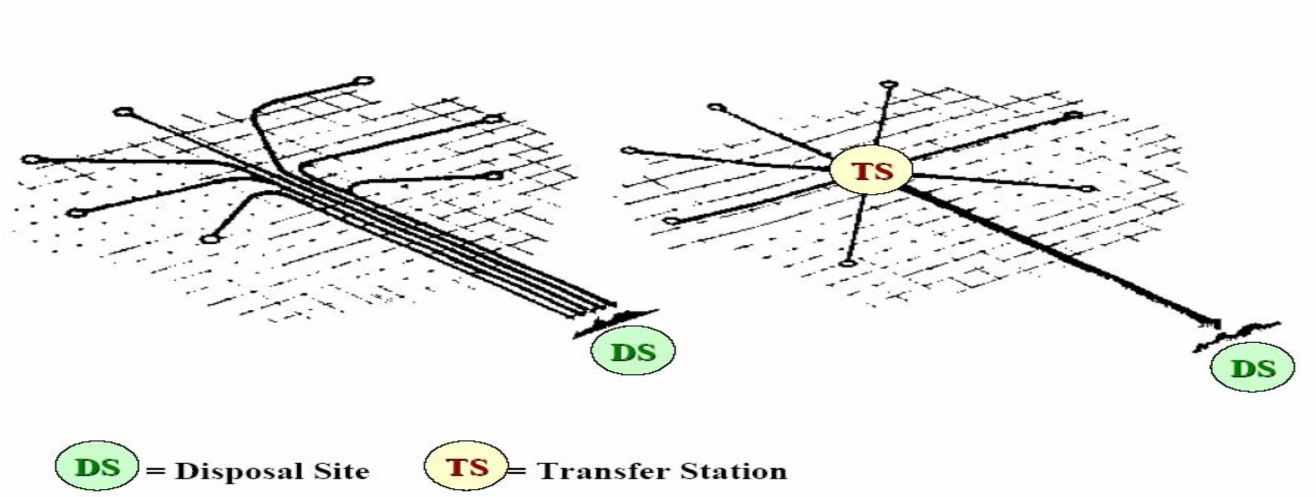


Figure 7-1: Options to transport solid waste

Source: Adapted from Ref.4

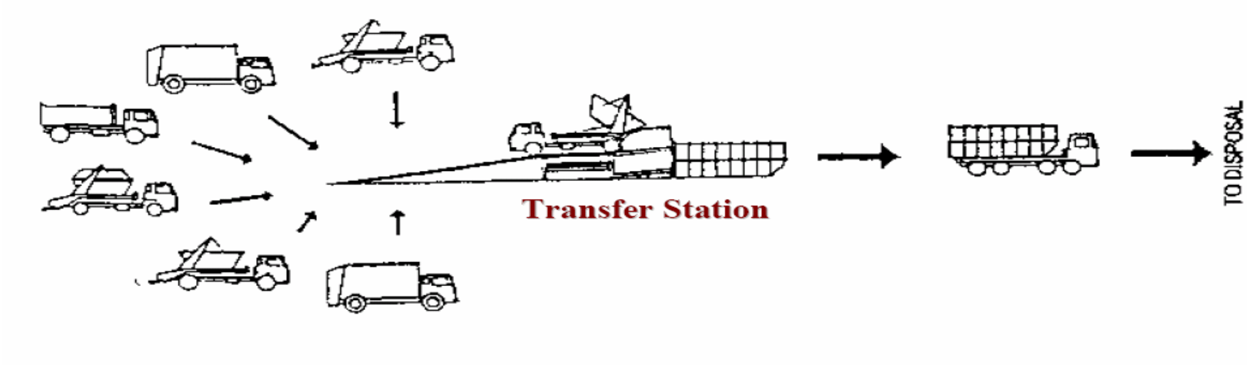


Figure 7-2: Solid waste transfer station

Source: Adapted from Ref.4

7.3 Review Questions

1. Why and when transport and transfer stations of solid wastes desired?
2. What are factors that should be considered during designing a transfer station and selecting equipment?

CHAPTER EIGHT

SOLID WASTE DISPOSAL

8.1. Learning objectives.

By the end of this chapter, the students will be able to:

1. describe the purposes of proper solid waste disposal.
2. discuss the different solid waste disposal methods
3. compare sanitary land fill and incineration as final disposal system for solid waste

8.2 Introduction

Until relatively recently, solid waste was dumped, buried, or burned, and some of the garbage was fed to animals. The public was not aware of the links of refuse to rats, flies, roaches, mosquitoes, fleas, land pollution, and water pollution. People did not know that solid waste in open dumps and backyard incinerators support breeding of diseases vectors including typhoid fever, endemic typhus fever, yellow fever, dengue fever, malaria, cholera, and others. Thus, the cheapest, quickest, and most convenient means of disposing of the waste were used. Rural areas and small towns utilized the open dump or backyard
incinerator. Larger towns and cities used municipal incinerators. Later, land filling became the method of choice for disposing of solid waste.

In solid waste management disposal is one of basic programs that has to be done with maximum precautions. If it is not done effectively and efficiently, the whole program will not be satisfactory.

Strictly speaking the task of solid wastes disposal is normally handled by a municipal, city or town authorities, if such service exists.

Disposal of solid waste has to be accomplished without the creation of nuisance and health hazards in order to fill full the objectives of solid waste management program. These are:

- improvement of esthetic appearance of the environment
- avoidance of smells and unsightliness.
- reduction of disease by curtailing fly and rodent breeding
- prevention of human and stray dogs from scavenging

In disposal of solids wastes, it is recommended that the following will be done to avoid any risks:

- the disposal site to be 30 meters from water sources in order to prevent possible contamination
- prevention of underground waster pollution should be taken into account
- radioactive materials and explosives should not be together.
- site should be fenced to keep way scavengers.
- all surface of dump should be covered with materials
- all wastes should be dumped in layers and compacted.
- disposal site should be about 500 meters from residential areas

8.3 Solid waste disposal methods

Generally there are several methods of solid waste disposal that can be utilized. These methods are:

1. Ordinary open dumping
2. controlled tipping/burial
3. Hog feeding
4. Incineration
5. Sanitary landfill
6. Composting
7. Grinding and discharge in to sewer
8. Dumping into water bodies
9. Disposal of corpus

1. Open dumping

Some components of solid waste such as street sweepings, ashes and non combustible rubbish are suitable for open dumping. Garbage and any other mixed solid wastes are not fit or suitable because of nuisance and health hazard creation. Generally, solid waste is spread over a large area, providing sources of food and harborage for flies, rats and other vermin. It causes unsightly odor and smoke nuisance and hazards. Carefully selected rubbish must be disposed in order to prevent fire accidents that might occur. The location of open dumping must be carefully chosen so that there will be a minimum chance of complaints from near by residents.

Advantage of open dumping

- Can take care of all types of solid wastes except garbage
- It causes less health problem if proper site is selected.
- Needs less labor and supervision

Disadvantage of open dumping

- Attraction of flies, mosquitoes and other insects as well as stray dogs, rats, and other animals.
- Creation of breeding sites for rodents, arthropods and other vermin
- Creation of smoke, odor and nuisance
- It makes the lands and other surrounding areas useless.
- It leads to cuts and wounds.
- It attracts scavengers, both humans and animals.

The following points should be kept in mind and must be considered before selection and locating sites for open dumping.

- Sources of water supply and distance from it
- Direction of wind
- Distance from nearest residents near by farm areas and main land
- Distance that flies can travel from disposal site to the living quarter as well as the distance that the rodents can travel from disposal areas and living quarters.

Negligence to these and some other factors would lead unforeseen health problems; if at all this method is selected.

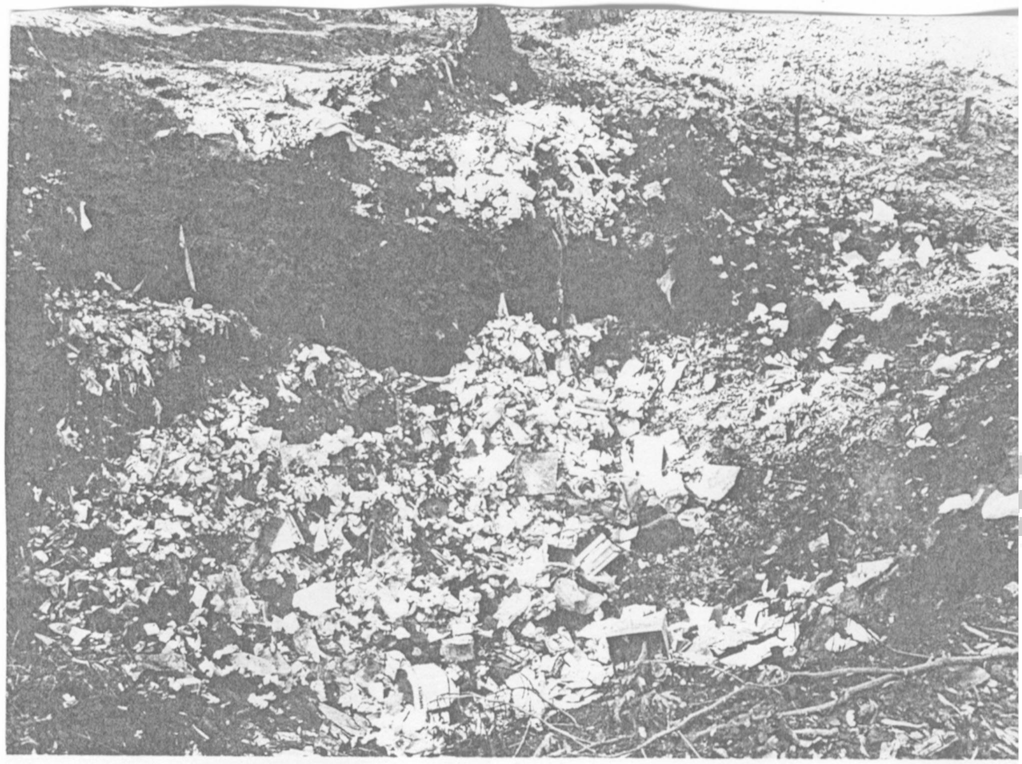


Figure 8-1. Uncontrolled solid waste disposal.
Source: Sandra J. Cointreau: Environmental Management Of Urban Solid Wastes in Developing Countries.

2. Controlled tipping/burial

Indiscriminate dumping of garbage and rubbish create favorable conditions for fly-breeding, harborage and food for rodents, nuisances etc. In order to avoid such problems, garbage and rubbish should be disposed of under sanitary conditions.

One of the simpler and cheaper methods is burning garbage and rubbish under controlled conditions. Controlled or engineered burial is known as Controlled Tipping or Sanitary Land Fill System. In places where there is no organized service, this system can be done by digging shallow 2 trenches, laying down the generated waste in an orderly manner, compacting the waste manually or mechanically and covering with adequate depth of earth or ash at the end of each day's work. The process is repeated each day systematically at appropriate locations. If properly done this system can prevent fly-breeding, rodent harborage, mosquito-breeding and nuisances. It can be applied in areas where appropriate land is available for such practice. This system can be considered an adaptation of what is technically called the SANITARY LAND FILL system in municipal solid wastes management service. Principally it consists of the following steps.

- Choosing suitable site, usually waste land to be reclaimed within reasonable distance from habitation.
- Transporting the generated wastes to the site by appropriately designed vehicles.
- Laying the wastes in appropriate heap to a pre-determined height.
- Compacting the layer mechanically
- Covering the compacted layer with a thin layer of earth 22 cm depth at the end of each work day. The same steps are repeated for each work period.

3. Hog feeding

The feeding of garbage to hogs has been practiced for many years in different parts of the world. But there is surprising high incidence of trichinosis among hogs which are fed with uncooked garbage.

Consumption of insufficiently cooked meat from hogs is believed to be the main source of trichinosis. Hogs which are fed on garbage containing hogs scraps and slaughter house offal are very likely to be infected. Also rats living around the slaughter house are infected and there is possibility that hog eats dead rats.

Trichinosis worm is easily killed only at a temperature of 58 ^{0}C. So the pork should be cooked until this temperature is obtained. Refrigeration at -35 ^{O}C for a period of 30 days will also kill the larva. Pickling, salting and smoking also kill the larva when done thoroughly. Garbage feeding is profitable if properly handled by farmers and if they are willing to use them by collecting it them selves. They should collect it daily and furnish clean cans while garbage is the most potential valuable element or component of solid waste. It is the most difficult to handle in a sanitary manner and is responsible for the majority of nuisances and health hazards associated with the disease. To use garbage for hog feeding it has to be cooked at temperature of 100 ^{0}C for 30 minutes just to be on safe side. Cooking the garbage before Hog feeding will not reduce the food value.

4. Incineration

Incineration is a process of burning the combustible components of garbage and refuse. Disposal of solid waste by incineration can be effectively carried out in small scale in food service establishments as well as in institutions such as hospitals, schools etc.

The disadvantage of this method is that only combustible materials are incinerated, hence there is a need for separation of the waste into combustible and non-combustible. The non-combustible needs separate disposal. Generally there are two types of incinerators, the open and the closed systems.

In the open system the refuse is incinerated in a chamber open to the air; while the closed system contains a special chamber designed with various parts to facilitate incineration. It requires a chimney of appropriate height to provide a good flow of air thorough the combustion chamber. There are varieties of designs for small scale incinerators. A typical example of design is shown in Figure 8-2. The size can be varied depending on the volume of the refuse to be incinerated.

The combustion chamber laid with iron grids, at the bottom of which are air inlets in front and at the back.

- The front and back walls with provision for installing chimney.
- The feeding door with baffle wall to facilitate refuse feeding.
- The base below the combustion chamber for collecting.

On-site Incineration

This term applies to incineration of refuse at home, office, apartment house, commercial building, hospital or industrial site. Refuse collection and disposal could be much reduced satisfactory by using on-site incineration. Generally, air-pollution can be expected.

Advantages of an incinerator

1. Less land is required than for landfills
2. A central location is possible - allow short hauling for the collection service.
3. Ash and other residue produced are free of organic matter, nuisance- free, and acceptable as fill material.
4. Many kinds of refuse can be burned. Even non-combustible materials will be reduced in bulk.
5. Climate or unusual weather does not affect it.
6. Flexibility is possible - no restriction for its operation
7. Getting income through the sale of waste heat for steam or power is possible.

Disadvantages of an incinerator

1. Initial cost is high - during construction
2. Operating cost is relatively high
3. Skilled employees are required for operation and maintenance
4. There may be difficulty in getting a site.

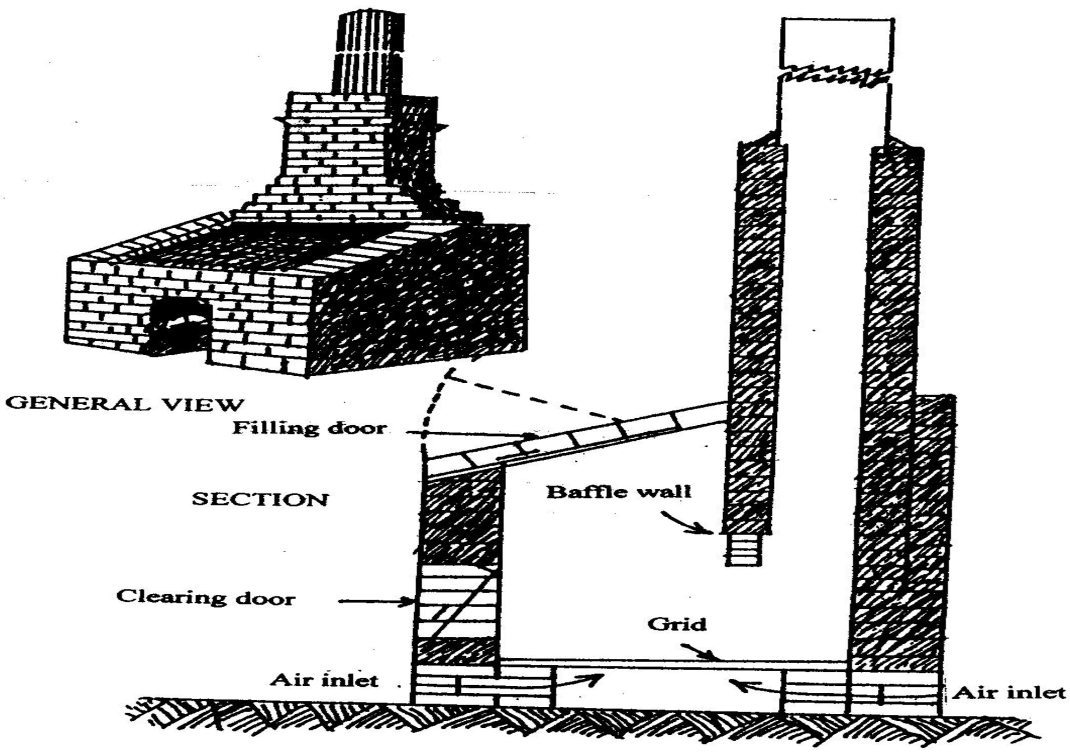


Figure 8- 2. Single chambers onsite incinerator

Source: Gabre-Emanuel Teka (1997): Solid waste disposal from food premise; In Food Hygiene.

An example of this type is commonly seen in some institutions in Ethiopia. A typical design consists of the following dimensions: width = 110 cm; length =110cm; height in front = 135cm; height at back =150cm. Concrete base (chamber)= 60cm by 75cm by 10cm top fueling door = 60cm by 60cm square, with thickness 5cm.With proper management and little fueling the incinerator can effectively burn dry as well as wet materials.

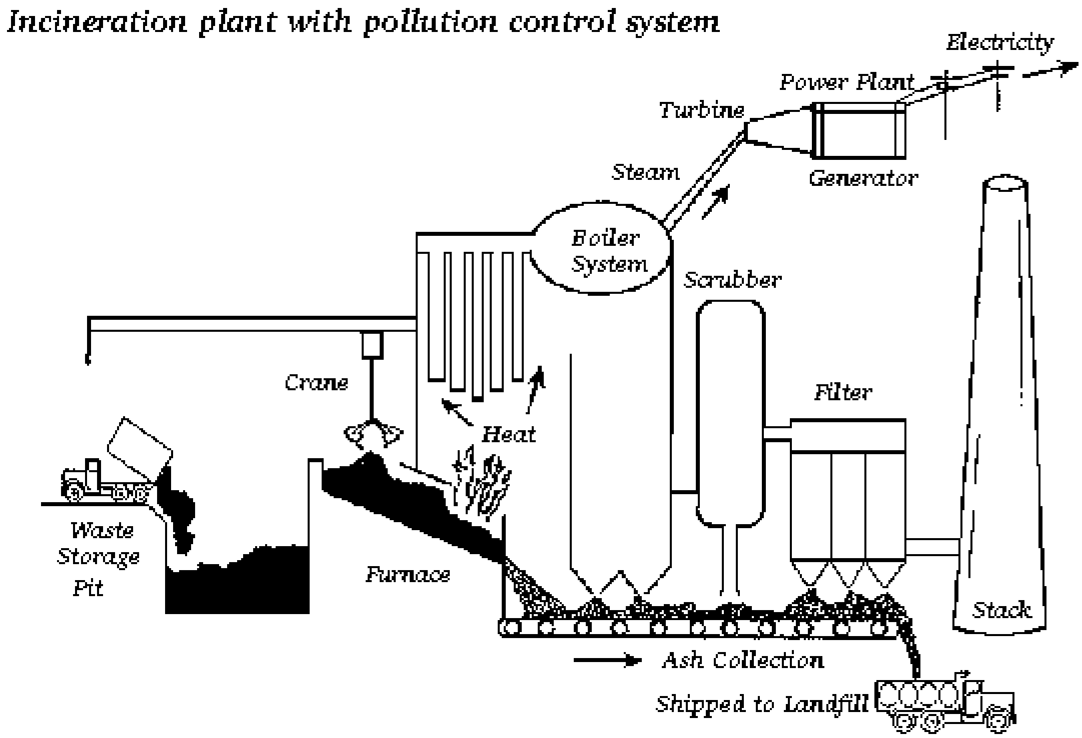


Figure 8-3 Incinerator with pollution control system

Source: Adapted from Ref.4

5. Sanitary landfill

Landfill design, construction, and operation

The problem of managing the increased volume of solid waste is compounded by rising public resistance to siting new landfills. There are five general phases of landfill construction:

- site selection;
- site investigation;
- design;
- daily operation; and,
- landfill completion or closure.

These stages are discussed in further detail below.

Site selection criteria include items such as availability of land, good drainage, availability of suitable soil for daily and final cover, visually isolated, access to major transportation routes, certain distance away from airport, not located in wetlands, and out of a floodplain. The engineer should also consider what the final use of the site will be and how long-term management of the site will impact this final use.

After a suitable site is identified, a site investigation is then performed. The site investigation includes items such as performing:

1) a topographic survey for surface contours and features (used also to estimate amount of available soil),

2) a hydrologic survey that looks at how the local hydrology will impact drainage requirements, and

3) a hydrogeology survey that will determine underlying geological formations and soil types, the depth to the groundwater table, the direction of groundwater flow, and the current quality of the groundwater (so one can determine whether the landfill is adversely impacting groundwater quality).

Landfill design and operation is the next step in the engineering process. Engineers have to consider the method of land filling and design the landfill interface (soil foundation, liners), leachate collection and treatment systems, and gas collection and venting system. The engineer also has to consider the selection of equipment that is used for hauling, excavating, and compaction; access to haul roads, fencing, and the storage and use of soil that is used for daily and final cover.

During daily operation, topsoil is removed and stored; refuse is transported into the site, dumped, and compacted; daily soil cover is placed over the refuse; groundwater is monitored; and, leachate is collected and treated.

The primary methods used for landfill are called:

1) the area method;

2) the trench method; and,

3) the depression method.

The area method is used when the site conditions do not allow the excavation of a trench. Typically an earthen levy is constructed and refuse is placed in thing layers against this levy and compacted. In a day, the compacted waste will reach a height of approximately 200 to300 meters and at the end of the day, a minimum of 15 centimeters inches of daily soil cover is applied as a barrier to disease vectors (e.g., it prevents the hatching of flies and the burrowing of rodents) and also prevents fires, odors, scavenging, and blowing litter. When the final design height is reached, a final soil cover is placed on top of the material. Each of the day's work of refuse is entombed in a "cell."

The trench method is most suitable in locations where the depth to the groundwater table does not prevent one from digging a trench in the ground. In this method, a trench is excavated with a bulldozer. Refuse is then placed in the trench and placed in thin layers that are compacted. The operation continues for the day until the desired daily height is reached. Again, daily cover is placed over the refuse to produce a "cell."

The depression method occurs at sites where natural features such as canyons, ravines, dry borrow pits, and quarries are available that can be filled in. Care is given to the hydrology of the site. For example, canyons are filled from the inlet to the outlet to prevent backing up of water behind the deposited refuse.

When the landfill has exhausted its life, a final cover is placed on top of the landfill; topsoil is replaced on the site and the site is landscaped; groundwater is continuously monitored; leachate is continuously collected and treated; and, gases are continuously collected and vented.

Leachate production and groundwater monitoring. Leachate is the liquid that percolates through a landfill. It is very high in concentration of water quality parameters. An engineer designs a landfill to minimize movement of water into the mass of refuse and thus attempts to minimize the production of leachate. The leachate collection system must be designed to keep the depth of the leachate over the liner to less than 30 cm.

Landfills are lined with either compacted clay or some type of geosynthetic liner. The purpose of these systems is to greatly reduce the hydraulic conductivity in the liner that minimizes the flow of leachate through the liner.

If compacted clay is used, it is typically 15 t0 120 centimeters thick and it is very important that the clay liner be compacted properly and not be allowed to dry out or crack. Geosynthetic liners are gaining widespread popularity and their installation is extremely important so that seams are sealed properly. Lying on top of this liner system is a leachate collection system, and on top of this is the compacted solid waste.

Generally, ground-water monitoring is conducted at all landfills. In fact, Environmental Protection Agency (EPA) requires that owners/operators install enough ground-water monitoring wells in the appropriate places to accurately assess the quality of the uppermost aquifer 1) beneath the landfill before it has passed the landfill boundary (to determine background quality) and 2) at a relevant point of compliance (down gradient).

Owners/operators should consider the specific characteristics of the sites when establishing their monitoring systems, but the systems must be certified as adequate by a qualified ground-water scientist or the director of an EPA-approved state/tribal program.

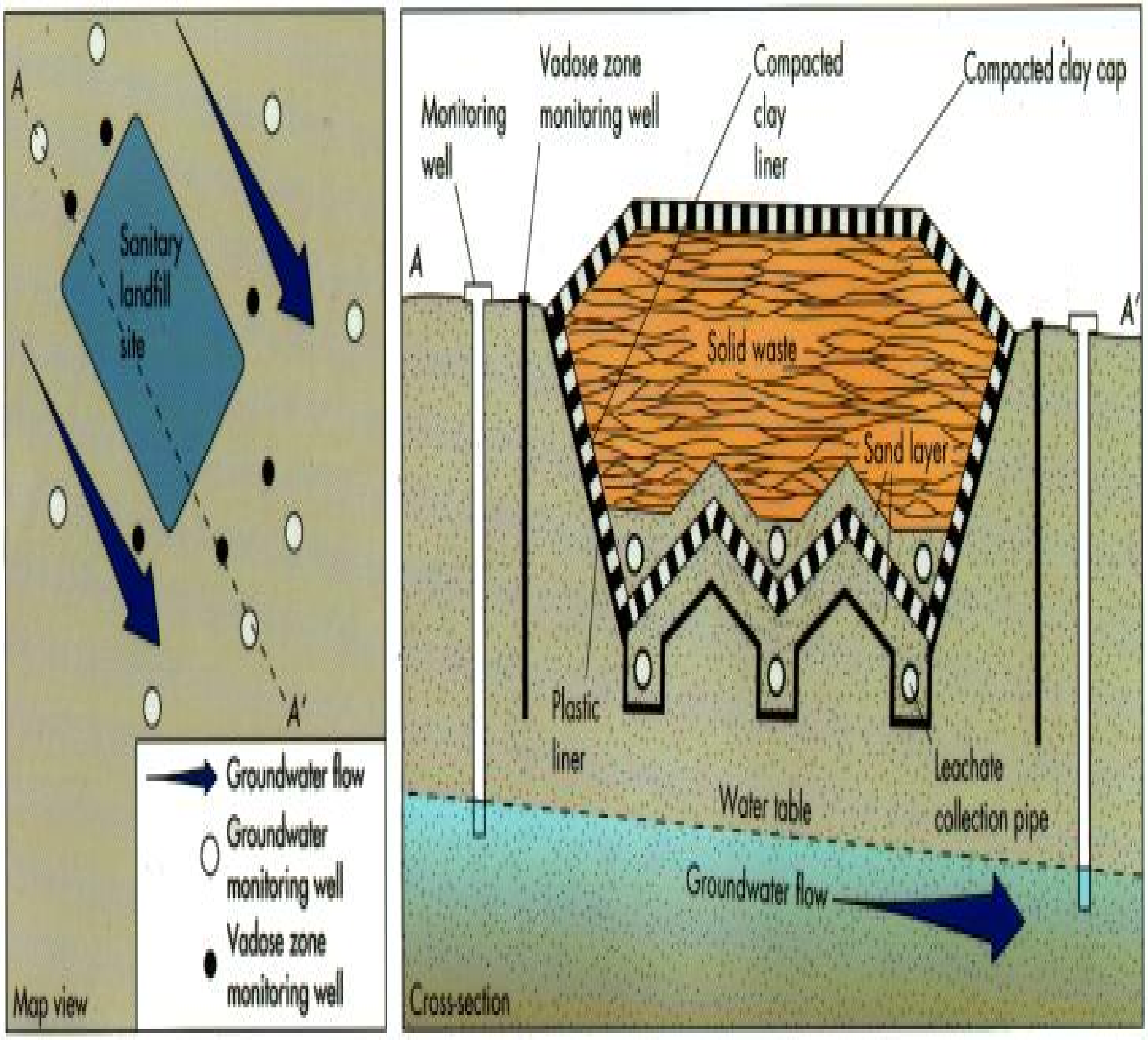


Figure 8-4: Landfill with plastic, clay liner and collection pipes to prevent leachate from entering the groundwater

Source: Adapted from Ref.10

Fundamental mechanisms for biodegradation of organic waste in a landfill

The biodegradation of organic waste in a landfill has five distinct phases, all of which influence the leachate composition and the development of landfill gas (LFG). In an enhanced bioreactor landfill, the time that elapses between these phases may be reduced. The five phases are illustrated in the Figure 8-5 below.

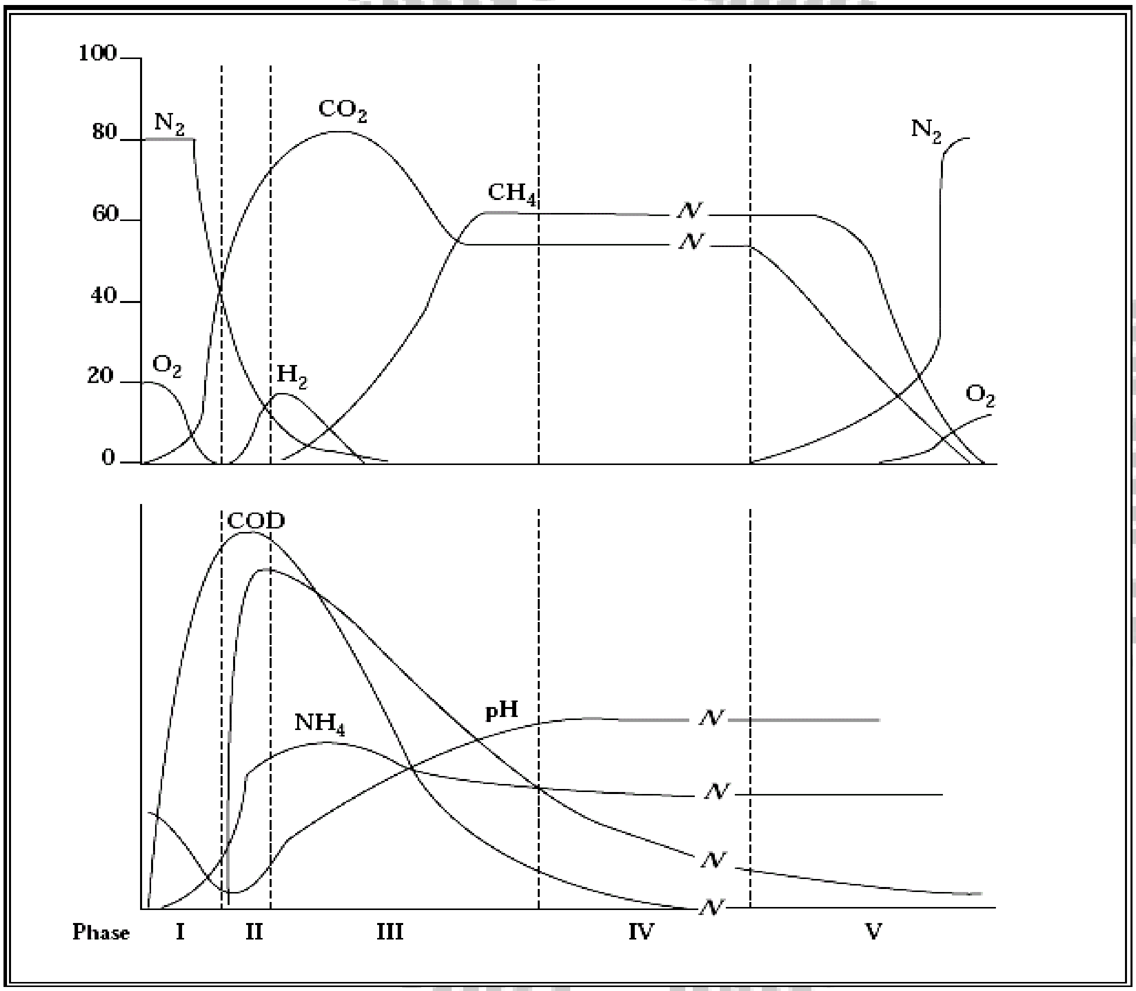


Figure 8-5: Idealistic Development of landfill gas and Leachate within a Landfill Cell

Source: Adapted from Ref.4

They are described as follows:

Phase I: This is an aerobic phase that takes place immediately after the waste is disposed of. Easily biodegradable substances are broken down by the presence of oxygen. In fact, this is a composting process where carbon dioxide is produced and the temperature rises. This phase may be very short lived.

Phase II: This is an aerobic phase, with the development of anaerobic conditions. A fermentation process occurs, developing acids in the leachate and a significant drop in pH. This process may lead to the release of metals in the waste matrix. The landfill gas generated consists primarily of carbon dioxide.

Phase III: Anaerobic conditions are now established. Within the right microbial environment, methanogenic conditions will emerge. The landfill gas will start to contain increasing quantities of methane, and the concentration of carbon dioxide will decrease. Sulfate will be reduced to sulfites and will be capable of precipitating metals from the leachate. As the organic acids are converted into landfill gas , the pH levels rise in the leachate. The organic load in the leachate will decrease, and ammonia will increase since ammonia is not converted under anaerobic conditions.

Phase IV: This is the so-called stable methanogenic phase. This is also the anaerobic phase, where methane production is at its highest, with a stable concentration of 40-60% CH_4 by volume. Acidic organic components in the leachate are immediately decomposed into landfill gas . The organic load in the leachate is low and consists primarily of heavy biodegradable organic components. As the conditions are strictly anaerobic, the leachate will still have a high concentration of ammonia.

Phase V: During this stabilizing phase, methane production will begin to decrease and the presence of atmospheric air will reintroduce aerobic conditions. This condition may occur only after several decades in shallower landfills. In deeper landfills, this stage may be reached only after many decades.

Closure When a landfill has reached its capacity, it is ready for closure. The final cover must be designed and constructed to have a permeability less than or equal to the bottom liner system or natural subsoil, or a permeability no greater than 1x10-5 cm/sec, whichever is lower.

The final cover must be constructed of an infiltration layer composed of a minimum of 45 centimeter of earthen material to minimize the flow of water into the closed landfill. The cover must also contain an erosion layer to prevent the disintegration of the cover. The erosion layer must be composed of a minimum of 15 centimeter of earthen material capable of sustaining plant growth.

When a landfill's bottom liner system includes a flexible membrane or synthetic liner, the addition of a flexible liner in the infiltration layer cover will generally be the only design that will allow the final cover design to achieve a permeability less than or equal to the bottom liner. In addition, for 30 years after closure, the owner/operator is responsible for maintaining the integrity of the final cover, monitoring ground water and methane gas, and continuing leachate management.

A sanitary landfill is a site where solid wastes are placed on or in the ground at a carefully selected location by means of engineering techniques that minimize pollution of air, water and soil, and other risks to man and animals. Aesthetic considerations are also taken into account.

In some major cities loans or grants have been used to construct sanitary landfills on sites that have been carefully chosen, but usually little attention is paid to the training of a site manager and to the provision of sufficient financial and physical resources to allow a reasonable standard of operation. As a result, some sites quickly degenerate into open dumps. It is crucial to good operations to have a motivated and trained site manager. It is recommended that the training for this position should include practical experience on well-run sites.

Most sanitary landfill designs attach considerable importance to preventing polluted water (leachate) from escaping from the site. It has been shown that large quantities of leachate can be produced by landfills, even in semi-arid climates. Most designs include expensive and carefully constructed impermeable layers which prevent leachate moving downwards into the ground and drainage systems to bring the leachate to a treatment plant or a storage tank. However, if the tank is not emptied before it overflows, or if the plant is not working, the leachate control system actually makes the pollution worse than from an open dump, because all the leachate is concentrated in one place, giving natural purification systems very little chance of reducing the pollution impact. This example shows that good design and construction can achieve nothing if they are not followed by good operation.

Landfill operation site layout

In planning the layout of a sanitary landfill site, the location of fill must be determined by:-

a. access roads

b. equipment shelters

c. scales to weigh wastes of needed

d. storage site for special wastes

e. top soil stock pile sites

g. landfills area and extension

A. Operation schedule

- arrival sequence for collection vehicles
- traffic patterns at the site
- time sequence to be followed in the filling operation.
- effects of wind and other climatic conditions
- commercial and public access

B. Equipment requirement

The type, size and amount of equipment required for sanitary landfill will be governed by size of community served, the nature of site the selected, the size of the landfill and the methods of operation. The types of equipment that have been used at sanitary landfill include:

1. crawler.
2. scrapers
3. compactors
4. water trucks.

C. Personnel

If there are advanced mechanical equipment without the facilities for a sanitary land fill serving less than 10,000 persons, the equipment operator would be the only person employed at site.

On large scale operations it is desirable to employ supervisor. In this case the supervisor should be able to operate the equipment in order to replace the employed operator in case of absence.

D. Accessory facilities

In addition to the equipment and personnel indicated above certain facilities are required at the site. These are:-

1. shade or shelter for equipment and personnel
2. rest room facilities
3. signs to direct trucks
4. portable or semi portable fencing
5 scale for weighing of trucks
6. hand sprayer for insecticidal application
7. portable pump for removal of accumulated surface water

E Determining Working Face and Phase Dimensions

The operating plan should describe, in detail, the configuration of the working face of the landfill. A typical cross section of a portion of a municipal landfill is illustrated in the figure below, including the "working face," and helps to define terms. The "working face" is the area presently being worked, with new refuse being deposited and compacted into it. Once the working face has been completed and daily cover material provided, it is a completed cell or "daily cell." A "lift" is composed of the adjacent daily cells that form one layer of the landfill. Lift thicknesses are generally 2.4 to 6 meter. Larger landfills that accept more refuse per day have higher lift thicknesses. "Daily cover material," as shown in the Figure, is applied over the working face and can extend over the horizontal surface at the top of each daily cell, depending on how long the cover will be exposed to the environment. If the landfill is not expected to receive additional wastes, closure activities must begin within 30 days of the final receipt of waste. The requirement to begin closure ensures that a proper cover is installed at the landfill.

Uses of fill lands

Sanitary landfill can be used to improve eroded areas, marshy and other marginal lands. After settling such lands could be used as parks, golf sport fields, other recreational areas, sometime for air ports, parking lots and small construction sites, etc.

Advantages of sanitary landfill

- it is relatively economical and acceptable method
- initial investment is low compared to other proven methods
- the system is flexible - can accommodate increase in population
- may result in low collection cost, as it permits continued collection of refuses. All types of refuses may be disposed of.
- the site may be located close to or in populated areas, thus reducing the length of hauling cost of collection
- it enables the reclaiming of depression and sub marginal lands for use and benefits of the community
- completed landfill areas can be used for agricultural and other purpose
- unsightliness, health hazards and nuisance of open dumping can be eliminated
- may be quickly established
- several disposal sites may be used simultaneously

Disadvantages of sanitary landfill

- sometimes suitable land within economical hauling distance may not be available.
- relatively large areas of land are required.
- slow decomposition of refuse in fill
- an adequate supply of good earth cover may not be readily accessible.
- if not properly located seepage from fills into streams may increase the chance for stream pollution.
- needs a careful and continuous supervision by skilled personnel.
- if not properly done can deteriorate into open dumping. (ordinary dumping)
- special equipment are required.

Comparison of landfills versus Incinerator

Sanitary land fills	Incinerators
1. Low initial cost	1. High initial cost
2. May change locations	2. Fixed location
3. Low operational cost	3. Variable, may cost much money
4. Increased land value may	4.Desirable site may be expensive
5. Complete and final disposal for all refuses	5. Ash, cans, bottle etc.disposed of separately
6. Needs large land area	6. Does not need large land area

6. Composting

Composting is an effective method of solid waste disposal. In composting, biodegradable materials break down through natural processes and produce humus. It involves the aerobic biological decomposition of organic materials to produce a stable humus-like product. Biodegradation is a natural, ongoing biological process that is a common occurrence in both human-made and natural environments.

It is important to view compost feedstock as a usable product, not as waste requiring disposal. When developing and promoting a composting program and when marketing the resulting compost, program planners and managers should stress that the composting process is an environmentally sound and beneficial means of recycling organic materials, not only a means of waste disposal.

Up to 70 percent of the municipal solid waste stream is organic material. Yard trimmings alone constitute 20 percent of municipal solid waste stream. Composting organic materials can significantly reduce waste stream volume and offers economic advantages for communities when the costs of other options are high.

Developing and operating successful composting programs presents several challenges.

These challenges include the following:

- developing markets and new end uses
- inadequate or nonexistent standards for finished composts
- inadequate design data for composting facilities
- lack of experienced designers, vendors, and technical staff available to many municipalities
- potential problems with odors
- problems controlling contaminants
- inadequate understanding of the biology and mathematics of composting.

The feedstock determines the chemical environment for composting.

Several factors determine the chemical environment for composting, especially:
a) the presence of an adequate carbon (food)/energy source,
b) a balanced amount of sufficient nutrients,
c) the correct amount of water,
d) adequate oxygen, e) appropriate pH, and
f) the absence of toxic constituents that could inhibit microbial activity.

The ratio of carbon to nitrogen affects the rate of decomposition.

The ratio must be established on the basis of available carbon rather than total carbon. An initial ratio of 30:1 carbon: nitrogen is considered ideal. To lower the carbon: nitrogen ratios, nitrogen-rich materials (yard trimmings, animal manures, bio solids, etc.) are added.

Moisture content must be carefully monitored.

Because the water content of most feedstock is not adequate, water is usually added to achieve the desired rate of composting. A moisture content of 50 to 60 percent of total weight is ideal.

Excessive moisture can create anaerobic conditions, which may lead to rotting and obnoxious odors. Adding moisture may be necessary to keep the composting process performing at its peak. Evaporation from compost piles can also be minimized by controlling the size of piles.

Maintaining proper pH levels is important.

pH affects the amount of nutrients available to the micro organisms, the solubility of heavy metals, and the overall metabolic activity of the micro organisms. A pH between 6 and 8 is normal.

Planning a composting program involves these steps.

- Identify goals of the composting project.
- Identify the scope of the project—backyard, yard trimmings, source-separated, mixed municipal solid waste, or a combination.
- Get political support for changing the community's waste management approach.
- Identify potential sites and environmental factors.
- Identify potential compost uses and markets.
- Initiate public information programs.
- Inventory materials available for composting.
- Visit successful compost programs.
- Evaluate alternative composting and associated collection techniques.
- Finalize arrangements for compost use.
- Obtain necessary governmental approvals.
- Prepare final budget and arrange financing.
- Construct composting facilities and purchase collection equipment, if needed.
- Initiate composting operation and monitor results.

Short- and long-term waste management needs determine composting program goals.

Program goals may include one or more of the following:

- ❖ achieving mandated waste reduction goals through increased recycling.
- ❖ diverting specific materials, such as yard trimmings, bio solids, or any high moisture organic waste, from landfills and incinerators.
- ❖ using compost as a replacement for daily cover (soil) in a landfill. In this case only a portion of the material may be composted to meet the daily cover needs, and the quality of compost generated is not critical.
- ❖ use for erosion control on highways, reservoirs, etc

Political support for a composting project is critical.

It is important to inform elected officials and government agencies of the project's goals and the developer's plans for implementing the project. Winning approval from an informed public can also be important for obtaining public funding. Without public approval, composting programs are difficult to successfully implement.

Two-way communication with the public is critical.

An effective education program is crucial to winning full public support. New waste management practices require substantial public education. Providing information about the nature of composting may help dispel any opposition to sitting the composting facility. Potential problems such as odor should be openly and honestly discussed and strategies for addressing such problems developed.

The composting method chosen should be compatible with existing systems.

The composting option chosen must be compatible with existing processing systems. Communities should consider these factors:

- Preferences of the community
- Collection and processing costs
- Residual waste disposal costs
- Markets for the quality of compost produced
- Markets for recyclables
- Existing collection, processing and disposal systems.

There are four types of technologies for composting.

The four composting technologies are windrow, aerated static pile, in-vessel, and anaerobic composting. Supporting technologies include sorting, screening, and curing. The technologies vary in the method of air supply, temperature control, mixing/turning of the material, and the time required for composting. Their capital and operating costs also vary considerably.

The biological, chemical, and physical composting processes

Many factors contribute to the success of the composting process. This section provides a technical discussion of these factors and gives readers who lack a technical background a more in-depth understanding of the basic composting processes. Understanding these processes is necessary for making informed decisions when developing and operating a composting program.

Biological Processes

Peak performance by microorganisms requires that their biological, chemical, and physical needs be maintained at ideal levels throughout all stages of com- posting. Microorganisms such as bacteria, fungi, and actinomycetes play an active role in decomposing the organic materials. Larger organisms such as insects and earthworms are also involved in the composting process, but they play a less significant role compared to the microorganisms.

As microorganisms begin to decompose the organic material, the carbon in it is converted to by-products like carbon dioxide and water, and a humic end product—compost. Some of the carbon is consumed by the microorganisms to form new microbial cells as they increase their population. Heat is re- leased during the decomposition process.

Microorganisms have preferences for the type of organic material they consume. When the organic molecules they require are not available, they may become dormant or die. In this process, the humic end products resulting from the metabolic activity of one generation or type of microorganism may be used as a food or energy source by another generation or type of microorganism. This chain of succession of different types of microbes continues until there is little decomposable organic material remaining. At this point, the organic material remaining is termed compost. It is made up largely of microbial cells, microbial skeletons and by-products of microbial decomposition and un-decomposed particles of organic and inorganic origin. Decomposition may proceed slowly at first because of smaller microbial populations, but as populations grow in the first few hours or days, they rapidly consume the organic materials present in the feedstock.

The number and kind of microorganisms are generally not a limiting environmental factor in composting non-toxic agricultural materials, yard trimmings, or municipal solid wastes, all of which usually contain an adequate diversity of microorganisms. However, a lack of microbial populations could be a limiting factor if the feedstock is generated in a sterile environment or is unique in chemical composition and lacks a diversity of microorganisms. In such situations it may be necessary to add an inoculum of specially selected microbes. While inocula speed the composting process by bringing in a large population of active microbes, adding inocula is generally not needed for composting yard trimmings or municipal solid wastes. Sometimes, partially or to- tally composted materials (composts) may be added as an inoculum to get the process off to a good start. It is not necessary to buy “inoculum” from outside sources. A more important consideration is the carbon: nitrogen ratio, which is described in a later section.

Microorganisms are the key in the composting process. If all conditions are ideal for a given microbial population to perform at its maximum potential, composting will occur rapidly. The composting process, therefore, should cater to the needs of the Microorganisms and promote conditions that will lead to rapid stabilization of the organic materials.

While several of the microorganisms are beneficial to the composting process and may be present in the final product, there are some microbes that are potential pathogens to animals, plants, or humans. These pathogenic organisms must be destroyed in the composting process and before the compost is distributed in the market place. Most of this destruction takes place by controlling the composting operation's temperature, a physical process that is described below.

Chemical Processes

The chemical environment is largely determined by the composition of material to be composted. In addition, several modifications can be made during the composting process to create an ideal chemical environment for rapid decomposition of organic materials. Several factors determine the chemical environment for composting, especially: (a) the presence of an adequate carbon food)/energy source, (b) a balanced amount of nutrients, (c) the correct amount of water, (d) adequate oxygen, (e) appropriate pH, and (f) the absence of toxic constituents that could inhibit microbial activity.

Carbon/Energy Source

Microorganisms in the compost process are like microscopic plants: they have more or less the same nutritional needs (nitrogen, phosphorus, potassium, and other trace elements) as the larger plants. There is one important exception, however: compost microorganisms rely on the carbon in organic material as their carbon/energy source instead of carbon dioxide and sunlight, which is used by higher plants.

The carbon contained in natural or human-made organic materials may or may not be biodegradable. The relative ease with which a material is bio- degraded depends on the genetic makeup of the microorganism present and the makeup of the organic molecules that the organism decomposes. For example, many types of microorganisms can decompose the carbon in sugars, but far fewer types can decompose the carbon in lignins (present wood fibers), and the carbon in plastics may not be biodegradable by any microorganisms. Because most municipal and agricultural organics and yard trimmings contain adequate amounts of biodegradable forms of carbon, carbon is typically not a limiting factor in the composting process.

As the more easily degradable forms of carbon are decomposed, a small portion of the carbon is converted to microbial cells, and a significant portion of this carbon is converted to carbon dioxide and lost to the atmosphere. As the composting process progresses, the loss of carbon results in a decrease in weight and volume of the feedstock. The less-easily decomposed forms of carbon will form the matrix for the physical structure of the final product—compost.

Nutrients

Among the plant nutrients (nitrogen, phosphorus, and potassium), nitrogen is of greatest concern because it is lacking in some materials. The other nutrients are usually not a limiting factor in municipal solid waste or yard trimmings feedstocks. The ratio of carbon to nitrogen is considered critical in determining the rate of decomposition. Carbon to nitrogen ratios, however, can often be misleading. The ratio must be established on the basis of available carbon rather than total carbon. In general, an initial ratio of 30:1 carbon: nitrogen is considered ideal. Higher ratios tend to retard the process of decomposition, while ratios below 25:1 may result in odor problems. Typically, carbon to nitrogen ratios for yard trimmings range from 20 to 80:1, wood chips 400 to 700:1, manure 15 to 20:1, and municipal solid wastes 40 to 100:1. As the composting process proceeds and carbon is lost to the atmosphere, this ratio narrows. Finished compost should have ratios of 15 to 20:1.

To lower the carbon: nitrogen ratios, nitrogen-rich materials such as yard trimmings, animal manures, or bio solids are often added. Adding partially decomposed or composted materials (with a lower carbon: nitrogen ratio) as inoculum may also lower the ratio. Attempts to supplement the nitrogen by using commercial fertilizers often create additional problems by modifying salt concentrations in the compost pile, which in turn impedes microbial activity. As temperatures in the compost pile rise and the carbon: nitrogen ratio falls below 25:1, the nitrogen in the fertilizer is lost in a gas form (ammonia) to the atmosphere. This ammonia is also a source of odors.

Moisture

Water is an essential part of all forms of life and the microorganisms living in a compost pile are no exception. Because most compostable materials have lower-than-ideal water content, the composting process may be slower than desired if water is not added. However, moisture-rich solids have also been used. A moisture content of 50 to 60 percent of total weight is considered ideal. The moisture content should not be great enough, however, to create excessive free flow of water and movement caused by gravity. Excessive moisture and flowing water form leachate, which creates a potential liquid management problem and potential water pollution and odor problems. Excess moisture also impedes oxygen transfer to the microbial cells. Excessive moisture can increase the possibility of anaerobic conditions developing and may lead to rotting and obnoxious odors.

Microbial processes contribute moisture to the compost pile during decomposition. While moisture is being added, however, it is also being lost through evaporation. Since the amount of water evaporated usually exceeds the input of moisture from the decomposition processes, there is generally a net loss of moisture from the compost pile. In such cases, adding moisture may be necessary to keep the composting process performing at its peak. Evaporation from compost piles can be minimized by controlling the size of piles. Piles with larger volumes have less evaporating surface/unit volume than smaller piles. The water added must be thoroughly mixed so all portions of the organic fraction in the bulk of the material are uniformly wetted and composted under ideal conditions. A properly wetted compost has the consistency of a wet sponge. Systems that facilitate the uniform addition of water at any point in the composting process are preferable.

Oxygen

Composting is considered an aerobic process, that is, one requiring oxygen. Anaerobic conditions, those lacking oxygen, can produce offensive odors. While decomposition will occur under both aerobic and anaerobic conditions, aerobic decomposition occurs at a much faster rate. The compost pile should have enough void space to allow free air movement so that oxygen from the atmosphere can enter the pile and the carbon dioxide and other gases emitted can be exhausted to the atmosphere. In some composting operations, air may be mechanically forced into or pulled from the piles to maintain adequate oxygen levels. In other situations, the pile is turned frequently to expose the microbes to the atmosphere and also to create more air spaces by fluffing up the pile. A 10 to 15 percent oxygen concentration is considered adequate, although a concentration as low as 5 percent may be sufficient for leaves. While higher concentrations of oxygen will not negatively affect the composting process, they may indicate that an excessive amount of air is circulating, which can cause problems. For example, excess air removes heat, which cools the pile. Too much air can also promote excess evaporation, which slows the rate of composting. Excess aeration is also an added expense that increases production costs.

pH

A pH between 6 and 8 is considered optimum. pH affects the amount of nutrients available to the microorganisms, the solubility of heavy metals, and the overall metabolic activity of the microorganisms. While the pH can be adjusted upward by addition of lime or downward with sulfur, such additions are normally not necessary. The composting process itself produces carbon dioxide, which, when combined with water, produces carbonic acid. The carbonic acid could lower the pH of the compost. As the composting process progresses, the final pH varies depending on the specific type of feedstock used and operating conditions.

Wide swings in pH are unusual. Because organic materials are naturally well-buffered with respect to pH changes, down swings in pH during composting usually do not occur.

Physical Processes

The physical environment in the compost process includes such factors as temperature, particle size, mixing, and pile size. Each of these is essential for the composting process to proceed in an efficient manner.

Particle Size

The particle size of the material being composted is critical. As composting progresses, there is a natural process of size reduction. Because smaller particles usually have more surface per unit of weight, they facilitate more microbial activity on their surfaces, which leads to rapid decomposition. However, if all of the particles are ground up, they pack closely together and allow few open spaces for air to circulate. This is especially important when the material being composted has high moisture content. The optimum particle size has enough surface area for rapid microbial activity, but also enough void space to allow air to circulate for microbial respiration. The feedstock composition can be manipulated to create the desired mix of particle size and void space. For yard trimmings or municipal solid wastes, the desired combination of void space and surface area can be achieved by particle size reduction. Particle size reduction is sometimes done after the composting process is completed to improve the aesthetic appeal of finished composts destined for specific markets.

Temperature

All microorganisms have an optimum temperature range. For composting this range is between 32° and 60° C. For each group of organisms, as the temperature increases above the ideal maximum, thermal destruction of cell proteins kills the organisms. Likewise, temperatures below the minimum required for a group of organisms affect the metabolic regulatory machinery of the cells. Although composting can occur at a range of temperatures, the optimum temperature range for thermophilic microorganisms is preferred, for two reasons: to promote rapid composting and to destroy pathogens and weed seeds. Larger piles build up and conserve heat better than smaller piles. Temperatures above 65° C are not ideal for composting. Temperatures can be lowered if needed by increasing the frequency of mechanical agitation, or using blowers controlled with timers, temperature feedback control, or air flow throttling. Mixing or mechanical aeration also provides air for the microbes.

Ambient air temperatures have little effect on the composting process, provided the mass of the material being composted can retain the heat generated by the microorganisms. Adding feedstock in cold weather can be a problem especially if the feedstock is allowed to freeze. If the feedstock is less than 5° C, and the temperature is below freezing, it may be very difficult to start a new pile. A better approach is to mix cold feedstock into warm piles. Once adequate heat has built up, which may be delayed until warmer weather, the processes should proceed at a normal rate. Pathogen destruction is achieved when compost is at a temperature of greater than 55° C for at least three days. It is important that all portions of the compost material be exposed to such temperatures to ensure pathogen destruction throughout the compost. At these temperatures, weed seeds are also destroyed. After the pathogen destruction is complete, temperatures may be lowered and maintained at slightly lower levels (51° to 55° C).

Attaining and maintaining 55° C temperatures for three days is not difficult for in-vessel composting systems. However, to achieve pathogen destruction with windrow composting systems, the 55° C temperature must be maintained for a minimum of 15 days, during which time the windrows must be turned at least five times. The longer duration and increased turning are necessary to achieve uniform pathogen destruction throughout the entire pile.

Care should be taken to avoid contact between materials that have achieved these minimum temperatures and materials that have not. Such contact could recontaminate the compost.

Compost containing municipal wastewater treatment plant biosolids must meet United States

Environmental Protection Agency(USEPA) standards applicable to biosolids pathogen destruction. This process of pathogen destruction is termed "process to further reduce pathogens" . In case of U.S.A their own minimum criteria regulated through permits issued to composting facilities. A state's pathogen destruction requirement may be limited to compost containing biosolids or it may apply to all municipal solid waste compost.

Mixing

Mixing feedstocks, water, and inoculants (if used) is important. Piles can be turned or mixed after composting has begun. Mixing and agitation distribute moisture and air evenly and promote the breakdown of compost clumps. Excessive agitation of open vessels or piles, however, can cool the piles and affect the compost process

The Benefits of Composting

Municipal solid wastes contain up to 70 percent by weight of organic materials. Yard trimmings, which constitute 20 percent of the municipal solid waste stream, may contain even larger proportions of organic materials. In addition, certain industrial by-products—those from the food processing, agricultural, and paper industries—are mostly composed of organic materials. Composting organic materials, therefore, can significantly reduce waste stream volume. Diverting such materials from the waste stream frees up landfill space needed for materials that cannot be composted or otherwise diverted from the waste stream.

Composting owes its current popularity to several factors, including increased landfill tipping fees, shortage of landfill capacity, and increasingly restrictive measures imposed by regulatory agencies. In addition, composting is indirectly encouraged by states with recycling mandates that include composting as an acceptable strategy for achieving mandated goals, some of which reach 50-60 percent. Consequently, the number of existing or planned composting programs and facilities has increased significantly in recent years.

Composting may also offer an attractive economic advantage for communities in which the costs of using other options are high. Composting is frequently considered a viable option only when the compost can be marketed—that is, either sold or given away. In some cases, however, the benefits of reducing disposal needs through composting may be adequate to justify choosing this option even if the compost is used for landfill cover.

Composts, because of their high organic matter content, make a valuable soil amendment and are used to provide nutrients for plants. When mixed into the soil, compost promotes proper balance between air and water in the resulting mixture, helps reduce soil erosion, and serves as a slow-release fertilizer.

7. Grinding and discharge into sewers lines

There are three methods for the disposal of garbage into sewers.

1. Installation of individual grinders in houses and commercial establishments.
2. Installation of municipally operated grinding station located centrally.
3. Installation of grinders at sewage treatment plant and discharge grounded materials directly into incoming raw sewage or digestion tanks.

1. House hold grinders

They contribute no difficulties in sewer collection systems. Of course it may lead to an increase of solids in sewage treatment plants.

2. Municipal grinding stations.

The location of central grinding stations at convenient points along the sewer system or at the sewage treatment plant is required. It requires the separation of garbage from the refuse by households prior to collection to the disposal areas. Central grinding station should not be objectionable although care should be taken to provide treatment of odor that arises from the accumulated garbage. If at all garbage of all contributing population is discharged into sewer lines there will be an increase of suspended solids to 50 % or less. The water consumption with grinders will be about four liters per capita per day.

8. Dumping into water bodies

The dumping of solid waste into water bodies such as streams, rivers, lakes, seas, and oceans was once been one of the means of disposal. This is still practiced in some cities and towns located on banks of rivers or sea shores, even though it can be ineffective due to the washing of the wastes to the shores and interference of sanitation of the bathing area. Such a disposal method would be effective if the risk to animals (fish) is taken into consideration and direction of wind blow looked before dumping.

9. Disposal of dead bodies

There are certain methods that can be practiced in relation to disposal of dead bodies.

- Embalming

To delay the purification of dead bodies by injection of preservatives.

- Cremating

Burning of dead bodies which are practiced in certain religious sectors. It is considered to be the best and sanitary method. In addition, it helps in conservation of land .It is cheap as far as cost is concerned. It is not acceptable method culturally in Ethiopia.

- Disposal into water bodies.

This method is usually practiced by travelers in sea water such as Fishers, Naval forces and those army forces deal with submarines.

- Burial into the ground

It is the most common, old and traditional method practiced in area where there is no digging and land problem. The minimum depth for such method is 2 meter. It should be undisturbed for another burial in the same pit.

8.4. Review questions

1. What would be the personal, political, and social factors associated with changing behavior of other in terms of solid waste disposal?

2. What are the common solid waste disposal methods that are practiced in your community, college or University?

3. What are the advantages of sanitary land fill over incinerator?

4. What are the benefits of compos?

CHAPTER NINE

INSTITUTIONAL BASED SOLID WASTE MANAGEMENT

9.1 Learning Objectives

By the end of this chapter, the students will be able to:

1. define institutional solid waste
2. describe health-care institution waste.
3. explain the major characteristics of health-care institution waste.
4. discuss the public health importance of health- care institution waste.
5. describe the treatment and disposal methods for health-care institution waste.

9.2 Introduction

Institutional solid waste is a waste generated from public and government institutions: health care facilities, offices, religious institutes, schools, universities, etc. It consists of both non-hazardous and hazardous solid waste. This chapter mainly addresses health care facility solid waste and potential hazards of exposure to hazardous health-care waste.

9.3 Health care facilities solid wastes

The health care sector includes a diverse range of health care facilities and activities, ranging in size from large general and specialist hospitals to small medical and dental offices and clinics. Ancillary facilities in this sector include medical laboratories and research facilities, mortuary centers and blood banks and collection services. All of these facilities present common environmental and health and safety issues that need to be addressed at a scale appropriate to the size of the facility and its activities. The health care sector involves close contact among patients, health care providers, and support staff; extensive use of sharps and instruments designed for diagnostic and curative (invasive and non-invasive) procedures; and, utilization of pharmaceutical, chemical, radiological and other agents for diagnosis, treatment, cleaning and disinfection.

Maintenance of sanitary conditions, use of appropriate disinfection and sterilization techniques, provision of potable water and clean air for all operations, and nosocomial infection control are the basic infrastructure requirements for health care facilities. These elements are mandatory to improve the health of patients, prevent transmission of infections among patients and staff, and reduce hazards for employees and the host community.

As part of day-to-day operations, health care facilities generate a variety of wastes including air emissions, wastewater effluents, health care waste (e.g. infectious, pathologic and chemical) and municipal solid waste. Approximately 75-90% of the total waste stream is general health care waste, generated by administrative, housekeeping and maintenance functions. The remaining 10-25 % of waste includes infectious, pathologic and chemical wastes that are considered hazardous in nature and create a variety of serious health risks. These wastes pose numerous hazards and must be appropriately managed to avoid damage to the environment and human health.

9.4 Public health impact of health-care solid waste

Health care solid wastes have attracted considerable attention because of the emotional impact of seeing body parts amidst solid waste, and because of the increasing concern about viral infections such as HIV/AIDS and hepatitis B and C, where health-care workers-particularly nurses-are at greatest risk of infection through injuries from contaminated sharps (largely hypodermic needles). Other hospital workers and waste-management operators out-side health-care establishments are also at significant risk, as are individuals who scavenge on waste disposal sites (although these risks are not well documented). The risk of this type of infection among patients and the public is much lower. Certain infections, however, spread through other media or caused by more resilient agents, may pose a significant risk to the general public and to hospital patients.

Individual cases of accidents and subsequent infections caused by health-care institution waste are well documented. The overall situation, however, remains difficult to assess, especially in developing countries. It is suspected that many cases of infection with a wide variety of pathogens have resulted from exposure to improperly managed health-care institution wastes in developing countries.

Table 9-1.Risk of infection after hypodermic needle puncture

Infection	Risk of infection
HIV	0.3%
Viral hepatitis B	3%
Viral hepatitis C	3-5%

Source: WHO (1999): Safe management of wastes from health- care activities

There were insufficient data on other infections linked to health-care institution waste to allow any conclusions to be reached. On the basis of the figures for HBV, however, it is recommended that all personnel handling health-care institution waste should be immunized against that disease.

If these data are to be extrapolated to developing countries like Ethiopia, it should be borne in mind that supervision and training of personnel exposed to waste in those countries may be less rigorous, with the result that more people are likely to be exposed to health-care institution wastes, both within and outside health-care establishments.

In any health-care establishment, nurses and housekeeping personnel are the main groups at risk of injuries; annual injury rates are 10-20 per 1000 workers. Highest rates of occupational injury among all workers who may be exposed to health-care institution waste are reported by cleaning personnel and waste handlers; the annual rate in the USA is 180 per 1000. Although most work-related injuries among health-care workers and refuse collectors are sprains and strains caused by overexertion, a significant percentage are cuts and punctures from discarded sharps.

The existence in health-care establishments of bacteria resistant to antibiotics and chemical disinfectants may also contribute to the hazards created by poorly managed health-care waste. It has been demonstrated, for example, that plasmids from laboratory strains contained in health-care waste were transferred to indigenous bacteria via the waste disposal system. Moreover, antibiotic-resistant Escherichia coli have been shown to survive in an activated sludge plant, although there does not seem to be significant transfer of this organism under normal conditions of waste-water disposal and treatment.

Concentrated cultures of pathogens and contaminated sharps (particularly hypodermic needles) are probably the waste items that represent the most acute potential hazards to health.

Sharps may not only cause cuts and punctures but also infect these wounds if they are contaminated with pathogens. Because of this double risk-of injury and disease transmission-sharps are considered as a very hazardous waste class. The principal concerns are infections that may be transmitted by subcutaneous introduction of the causative agent, e.g. viral blood infections. Hypodermic needles constitute an important part of the sharps waste category and are particularly hazardous because they are often contaminated with patients' blood.

Many of the chemicals and pharmaceuticals used in health-care establishments are hazardous (e.g. toxic, corrosive, flammable, reactive, explosive, shock-sensitive). These substances are commonly present in small quantities in health-care waste; larger quantities may be found when unwanted or outdated chemicals and pharmaceuticals are disposed of. They may cause intoxication, either by acute or by chronic exposure, and injuries, including burns. Intoxication can result from absorption of a chemical or pharmaceutical through the skin or the mucous membranes, or from inhalation or ingestion. Injuries to the skin, the eyes, or the mucous membranes of the airways can be caused by contact with flammable, corrosive, or reactive chemicals (e.g. formaldehyde and other volatile substances). The most common injuries are burns.

Disinfectants are particularly important members of this group: they are used in large quantities and are often corrosive. It should also be noted that reactive chemicals may form highly toxic secondary compounds.

Obsolete pesticides, stored in leaking drums or torn bags, can directly or indirectly affect the health of anyone who comes into contact with them. During heavy rains, leaked pesticides can seep into the ground and contaminate the groundwater. Poisoning can occur through direct contact with the product, inhalation of vapors, drinking of contaminated water, or eating of contaminated food. Other hazards may include the possibility of fire and contamination as a result of inadequate disposal such as burning or burying.

Chemical residues discharged into the sewerage system may have adverse effects on the operation of biological sewage treatment plants or toxic effects on the natural ecosystems of receiving waters. Similar problems may be caused by pharmaceutical residues, which may include antibiotics and other drugs, heavy metals such as mercury, phenols, and derivatives, and disinfectants and antiseptics.

Many attempts to upgrade healthcare waste management rely solely on the provision of incinerators or other treatment technologies. Such a strategy has several weaknesses in that

- often the hospitals and healthcare facilities are not able to afford the operating costs of the plant, and so the plants are left unused or not repaired when the break down;
- many of the risks occur before the waste gets to this final stage, and so they are not reduced by the provision of treatment equipment;
- the real need is often provide better methods of storage to train the staff to adopt safer working practices.

9.5. Sources of health care solid wastes

Major sources of health-care waste

- Hospitals: general, district
- University
- Emergency services, health-care centres, dialyses centres, first-aid posts, hospices, blood transfusion centres, dental clinics, acupuncturists
- Laboratories and research centres
- Animal research and testing institutes
- Blood banks and blood collection services
- Specialised health-care establishments: Nursing homes, psychiatric hospitals, disabled persons' institutions

9.6. Categories of health care solid wastes

- Medical wastes: These wastes are usually produced in patient rooms, treatment rooms and nursing stations, the operating room may also be a contributor, and items include soiled dressings, bandages, catheters, swabs, plaster casts receptacles, and masks. The hazardous waste is generated from both OPD and inpatient wards as a result of diagnosing, treating, or handling the patient.
- Surgical and autopsy (Pathologic wastes) these wastes may be produced in surgical or autopsy rooms, items that may be included are placenta, tissues and organs, amputated limbs, fetus and similar material.
- Laboratory wastes: these wastes are produced in diagnostic or research laboratories, items that may be included are cultures, spinal-fluid samples, dead animals, and animal bedding.
- Infectious solid wastes: proportion of medical waste that is infectious (dressings, laboratory and pathological wastes, contaminated blood discarded equipments, etc.)
- Domestic/general wastes: offices, kitchen wastes (non hazardous)
- Radio-active wastes: radiating residues produced as a result of radio therapy and diagnosis.
- Pharmaceutics
- Sharps

9.7. Management of health care solid wastes

The need for infectious and medical waste management now reaches beyond hospitals and medical centers to smaller waste generators such as clinics, colleges and universities, diagnostic laboratories, funeral homes, doctor's offices, and other health facilities. Infectious and medical waste produce occupational risks such as direct exposure to blood products, needle sticks, and infectious dressings by patients, visitors, and workers. Environmental risks include the possibility of pollution of groundwater, surface water, or air. Even small amounts of laboratory solvents can leach into drinking water. Incinerated medical waste may not destroy infectious agents, releasing them into the air, in the ash or via scrubber effluent.

Table 9-2.Basic elements for the safe management of health care waste

1 - Selection of options	2 - Awareness and training	3 - Implementation
• Choice of off site options :Identification of close by centralized waste management and disposal facilities that meet national regulations and are legally recognized as such • Choice of sustainable management and disposal options, according to: – Context and needs – Availability – Affordability – Environment-friendliness – Efficiency – Worker's safety – Prevention of the re-use of – disposable medical equipment (e.g. syringes) – Social acceptability • Process: Involve key stakeholders such as environmentalists, municipality and private sector.	• Awareness raising of all staff about risks related to sharps and other infectious wastes • Training of all health-care personnel regarding segregation practices • Training of waste workers regarding safe handling, storage and operation and maintenance of treatment technologies • Display of written instructions for personnel	• Assessment of the current HCW system in place • Joint development of a sound HCW system • Assignment of responsibilities for waste management • Allocation of sufficient resources • Waste minimization, including purchasing policies and stock management practices • Segregation of waste into sharps, non-sharps infectious waste and non-infectious waste (colour-coded system) • Implementation of safe handling, storage, transportation, treatment, practices and disposal options • Tracking of waste production and waste destination Evaluation of the HCW system

Source: Adapted from Ref.1

A. Waste minimization, recycling, and reuse

1. Waste minimization

Significant reduction of the waste generated in health-care establishments and research facilities may be encouraged by the implementation of certain policies and practices, including the following:

- Source reduction: measures such as purchasing restrictions to ensure the selection of methods or supplies that are less wasteful or generate less hazardous waste.
- Recyclable products: use of materials that may be recycled, either on-site or off-site.
- Good management and control practices: apply particularly to the purchase and use of chemicals and pharmaceuticals.
- Waste segregation: careful segregation (separation) of waste matter into different categories helps to minimize the quantities of hazardous waste.

Careful management of stores will prevent the accumulation of large quantities of outdated chemicals or pharmaceuticals and limit the waste to the packaging (boxes, bottles, etc.) plus residues of the products remaining in the containers. These small amounts of chemical or pharmaceutical waste can be disposed of easily and relatively cheaply, whereas disposing of larger amounts requires costly and specialized treatment, which underlines the importance of waste minimization.

Waste minimization usually benefits the waste producer: cost for both the purchase of goods and for waste treatment and disposal are reduced and the liabilities associated with the disposal of hazardous waste are lessened.

All health-service establishments employees have a role to play in this process and should therefore be trained in waste minimization and the management of hazardous materials. This is particularly important for the staff of departments that generate large quantities of hazardous waste.

Suppliers of chemicals and pharmaceuticals can also become responsible partners in waste minimization program. The health service unit can encourage this by ordering only from suppliers who provide rapid delivery of small orders, who accept the return of unopened stock, and who offer off-site waste management facilities for hazardous wastes.

Reducing the toxicity of waste is also beneficial; by reducing the problems associated with treatment or disposal.

2. Safe reuse and recycling

Medical and other equipment used in a health-care establishment may be reused provided that it is designed for the purpose and will withstand the sterilization process. Reusable items may include certain sharps, such as scalps and hypodermic needles, syringes, glass bottles and containers, etc. After use, these should be collected separately from non-reusable items, carefully washed and sterilized particularly in the case of hypodermic needles, in which infectious droplets could be trapped. Although reuse of hypodermic needles is not recommended, it may be necessary in establishments that cannot afford disposable syringes and needles. Plastic syringes and catheters should not be thermally or chemically sterilized; they should be discarded.

Certain types of container may be reused provided that they are carefully washed and sterilized. Containers of pressurized gas, However, Should generally be sent to specialized centers to be refilled. Containers that once held detergent or other liquids may be reused as containers for sharps waste (if purpose-made containers are not affordable) provided that they are puncture-proof and correctly and clearly marked on all sides.

Recycling is usually not practiced by health-care facilities, apart, per-haps, from the recovery of silver from fixing baths used in processing X-ray films. However, recycling of materials such as metals, paper, glass, and plastics can result in savings for the health-care facility—either through reduced disposal cost or through payments made by the recycling company.

In temperate climates, the heat generated by on-site incinerators may be an attractive and cost-effective option for heating hospital premises.

In determining the economic viability of recycling, it is important to take account of the cost of alternative disposal methods and not just the cost of the recycling process and the value of the reclaimed material.

B. Handling, storage, and transportation of health-care facility waste

1. Waste segregation and packaging

The key to minimization and effective management of health-care waste is segregation (separation) and identification of the waste. Appropriate handling, treatment, and disposal of waste by type reduce cost and does much to protect public health. Segregation should always be the responsibility of the waste producer, should take place as close as possible to where the waste is generated, and should be maintained in storage areas and during transport. The same system of segregation should be in force throughout the country.

The most appropriate way of identifying the categories of health-care facility waste is by sorting out the waste into color-coded plastic bags or containers.

In addition to the color coding of waste containers, the following practices are recommended:

- General health-care facility waste should be part of the stream of domestic refuse for disposal.
- Sharps should all be collected together, regardless of whether or not they are contaminated. Containers should be puncture-proof (usually made of metal or high-density plastic) and fitted with covers. They should be rigid and impermeable so that they safely retain not only the sharps but also any residual liquids from syringes. To discourage abuse, containers should be tamper-proof (difficult to open or break) and needles and syringes should be rendered unusable. Where plastic or metal containers are unavailable or too costly, containers made of dense cardboard

are recommended; these folds for ease of transport may be supplied with a plastic lining.

- Bags and containers for infectious waste should be marked with the international infectious substance symbol.
- Highly infectious waste should, whenever possible, be sterilized immediately by autoclaving. It therefore needs to be packaged in bags that are compatible with the proposed treatment process: red bags, suitable for autoclaving, are recommended.
- Small amounts of chemical or pharmaceutical waste may be collected together with infectious waste.
- Large quantities of obsolete or expired pharmaceuticals stored in hospital wards or departments should be returned to the pharmacy for proper disposal.

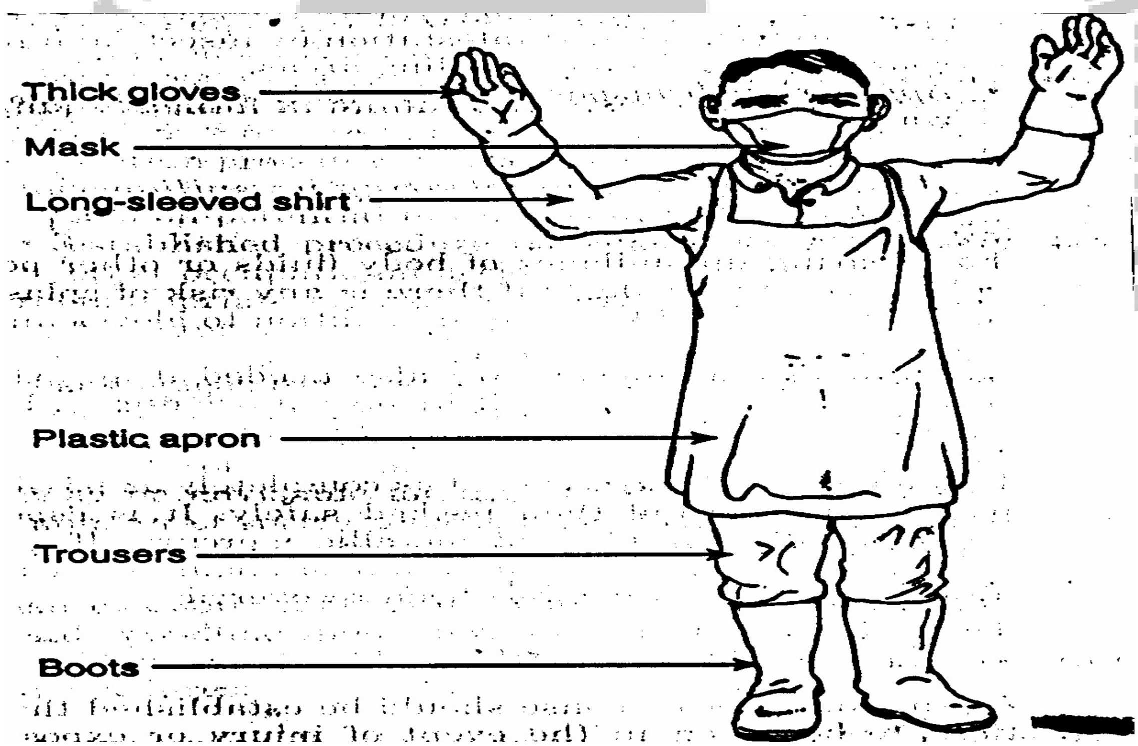


Figure 9-1. Recommended protective clothing for health care waste transportation.
Source: WHO (1999): Safe management of waste from health care facility activities.

C. Treatment and disposal technologies for health-care facility waste

The final choice of treatment system should be made carefully, on the basis of various factors, many of which depend on local conditions:

- Disinfection and sterilization efficiency;
- Health and environmental considerations;
- Volume and mass reduction;
- Occupational health and safety considerations;
- Quantity of wastes for treatment and disposal/capacity of the system;
- Types of waste for treatment and disposal;
- Infrastructure requirements;
- Locally available treatment options and technologies;
- Options available for final disposal;
- Training requirements for operation of the method;
- Operation and maintenance consideration;
- Available space;
- Location and surroundings of the treatment site and disposal facility;
- Investment and operating cost;
- Public acceptability;
- Regulatory requirements.

Several treatment technologies are available to dispose of health care establishment waste.

1. Incineration

Incineration uses controlled, high-temperature combustion process to destroy organisms in waste materials. Modern incineration systems are well engineered; high-technology processes designed to maximize combustion efficiency and completeness with a minimum of emissions of waste.

2. Open dumps

- uncontrolled and scattered deposit of wastes at a site
- Mostly practiced in health care delivery systems of Ethiopia.

- leads to acute pollution problems, fires, high risks of disease transmission and open access to scavengers animals.

3. Placenta pit

Certain basic rules should be fulfilled

- Access to the disposal site should be restricted to authorized personnel only
- The pit should be lined with a material of low permeability, such as clay.
- Only hazardous health-care facility waste including placenta should be buried
- The pit should be managed as a landfill process, with each layer of waste being covered with a layer of earth to prevent odors, as well as to prevent rodents and insects proliferation

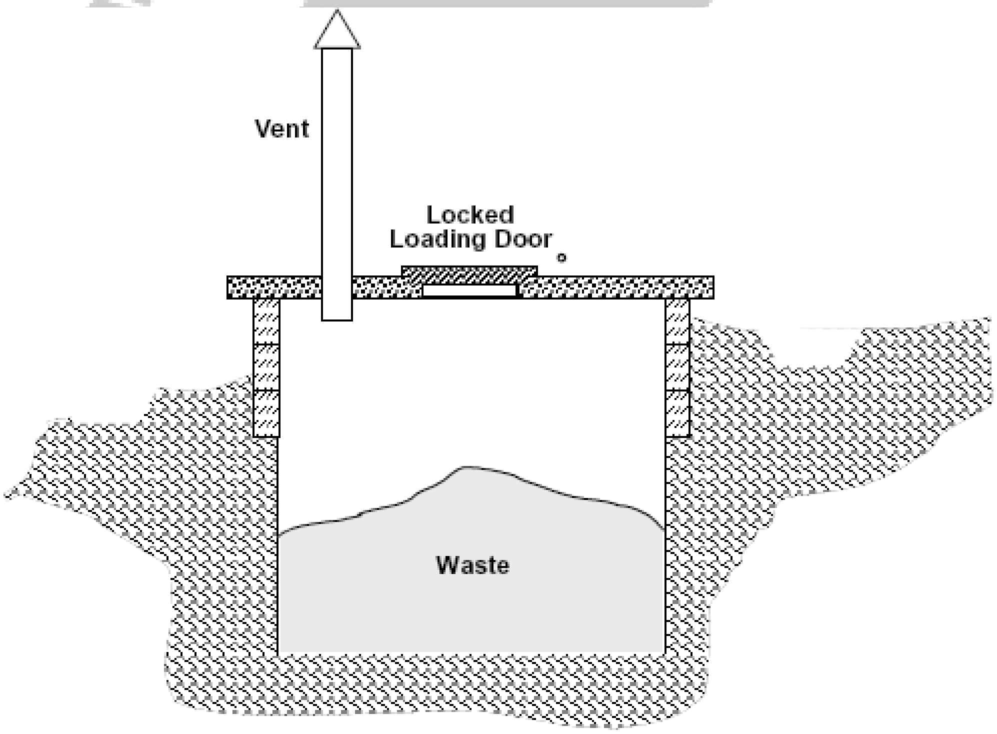


Figure 9-2 Cross-sectional View of secured placental pit

Source: Adapted from Ref.1

4. Steam Sterilization

The advantages of steam sterilization, or autoclaving are relatively low capital investment, operating cost, relatively small space requirements, and simplicity of operation. Disadvantages include limited capacity, the requirement of special waste packaging and handling, and odor and drainage problems. Autoclaving is not recommended for pathological wastes, waste with high liquid content, and waste contaminated with volatile chemicals. After autoclaving, the appearance of waste remains unchanged. Although needles, syringes, blood bags, and the like, are sterilized, they also are recognizable. This has the effect of making much of the waste unacceptable for disposal in a landfill or other disposal means. Also, compacting autoclaved waste tends to break open waste bags and other containers, exposing and spilling their contents. Consequently, waste haulers and landfill operators may not be willing to accept autoclaved waste in spite of its sterile condition.

9.8 Review questions

1. What is health- care facility waste?
2. What are the types of health care establishments wastes?
3. What are potentional health risks that can be associated with handling of health-care facility waste?
4. Who are at risk of health-care waste?
5. How can you dispose health care wastes?

CHAPTER TEN

COMMUNITY-BASED SOLID WASTE MANAGEMENT: PROBLEMS AND SOLUTIONS

10.1 Learning objectives

By the end of this chapter, the students will be able to

1. Discus the role of community members and local leaders in community-based solid waste management
2. Identify different organizational structures of community-based solid waste management
3. Describe social and management problems of community-based solid waste management

10.2. Introduction

The maintenance of established infrastructure and services has evolved as a major problem of development projects. In the words of a major solid waste expert, Christine Furedy: "In general, self-help efforts have been more successful in producing a specific object, such as a school, a latrine system or a solid waste transfer depot, than in maintaining services in a routine way". A solid waste management system is in fact a continuous maintenance system. To keep the service running, continuous participation of the community receiving the service, is required, for example, to store the garbage in a specific bag or bin, to bring it to an agreed point, to separate it in dry and wet waste etc. This means that community participation is a rather crucial aspect of solid waste management, may be even more important than in any other urban service. Only recently the management of solid waste services by communities themselves received attention.

There is no well organized community based solid waste management program in Ethiopia. Therefore the main purpose of this chapter is to learn lessons form other countries which are relevant to our setup.

10.3. The role of community members and local leaders in community-based solid waste management

A/ The role of community members: from behaving well to decision-making

Community members and local leaders in urban communities play different roles in solid waste management. Community members can participate in solid waste management by showing proper sanitation behavior, by contributions in cash, kind or labor, by participation in consultation and by participation in administration and management of solid waste services.

Proper sanitation behavior is behavior that facilitates solid waste management systems. It may include:

- Adapt daily habits to agreed solid waste system (rules, schedules, e.g. to offer it at the right time and place to the collection team)
- Bring garbage to communal collection point for transfer
- Store garbage in a plastic bag, a special bin etc.
- Cooperate in clean-up campaigns
- Keep house and immediate environment clean (drains, streets in front of the house)
- Separate waste in organic and non-organic, wet and dry, keep plastic, paper etc. apart
- Compost the organic fraction in own backyard

Some projects try to influence and change the sanitation behavior of households via education, awareness campaigns, etc. The effectiveness of these campaigns depends on the influence of the persons who carry out education and on the degree of social control within a neighborhood.

Contributions in cash, kind or labor are more direct contributions to the operation of solid waste management projects.

They usually involve:

- Regular fee payment for collection
- Donate or lend equipment to the collection team
- Contribute in labor with collection (voluntary or paid)

Money is needed to cover capital costs (to buy or rent equipment) and to cover daily expenses through collection fees. These fees sometimes cover both primary and secondary collection, but mostly community-based solid waste management projects are only involved in fees for primary collection. The ways of payment differ. Contributions in kind are less common; they include the grant of local materials and equipment by neighborhood residents. Labor inputs, on the contrary, are more current: voluntary contributions like helping with construction and arrangement of disposal sites, or with loading garbage in municipal vehicles. But salaried employment in the operation of a collection scheme, in a sorting and recycling centre or at a composting plant, is more common.

Participation in consultation may take place during a need assessment study or some other form of preliminary research, such as home visits and meetings organized by community based organizations to talk about the needs and problems regarding solid waste management. It may include:

- Answer preparatory research questions
- Attend meetings
- Elect leaders, representatives who manage waste collection
- Elect members of micro-enterprises
- Give feedback about collection system/waste services to operating team or management

Consultation may concern only the representatives of the community, or all sections of the community. This last option also includes minorities and disadvantaged groups such as youths, women, etc. The way of consultation determines the outcome that is whose needs are assessed, who will be the beneficiaries, etc. In solid waste management projects that require changes in behavior, such as cleaning, separation at source, recycling, and composting, preliminary studies are especially useful.

Participation in administration and management is the highest level of community participation in solid waste management. To this end, community members may:

- Take part in committees
- Become member of a community based organization (CBO) involved in waste collection, environmental education, etc.
- Participate in decision-making during meetings

Real community management involving all three aspects of responsibility, authority and control, as mentioned in the Introduction, is not very common in solid waste management. Using one criterion, control by a neighborhood committee, one can conclude that one third to half of the solid waste management projects studied are managed by the community. Only a small segment of the community is really active in the management of a garbage collection scheme, a recycling centre or a composting plant. Their tasks will be described in the next paragraph.

B/The role of local leaders: intermediaries between communities and municipalities

Local leaders can be divided into traditional, formal and informal leaders. Traditional leaders derive their authority from hereditary rights and from their status in the local culture. Formal leaders are appointed by the government or elected as local representatives of the government. Informal leaders are influential members of a community on the basis of their personal status or of their activities in community-based organizations such as political parties, churches, youth and women's organizations, neighborhood committees, etc. All three types of local leaders may have different roles in solid waste management. Usually formal and informal leaders are more involved in solid waste management than traditional leaders. Involvement in management of solid waste services includes participation in the management of solid waste services and keeping in contact both with the municipality and the community.

Management of solid waste services can be carried out by existing community-based organizations or by new committees particularly established for this purpose. Members of community based organizations may also participate in the management committee of a solid waste service. The tasks of this management committee can be defined as follows:

- Performance control of services
- Administration of activities
- Engage personnel for operation
- Manage fee collection
- Keep treasury
- Decision-making on operation

The management committee has the responsibility for the administration of activities, monitoring the work flow, managing manpower and means, and matching the objectives with the means. It has decision-making power and controls the operation of the service. The community member or members, who were responsible for taking the initiative, are often involved in management. Non governmental or governmental agency starting a solid waste management project, may also ask community members to be engaged in the management committee. A local leader such as the president of a community-based organization can also exercise supervision on a higher level, controlling the management committee.

Keeping in contact with the municipality may take different forms:

- Communicate about the coordination of primary and secondary collection systems
- Exercise political pressure on the municipality
- Forward complaints about performance service

A community-based organization may contact the responsible municipal agency to integrate primary and secondary collection. When no service is delivered to the area, or when certain equipment is needed, it can exercise political pressure on the municipality, the mayor, etc. Complaints on the secondary collection from households can be forwarded jointly by them to the municipality, or to the management committee when the complaints concern the primary collection system.

Regarding contacts with the community, local leaders may:

- Carry out education and awareness raising
- Control of behavior of households (watchdog function)
- Mobilize the community

A community-based organization may design and implement education campaigns, even if it is not directly involved in waste collection or treatment. Thus it can support collection services and change the behavior of households. It may also have a watchdog function, to control that the behavior of households conforms to the agreed rules and schedules. Traditional leaders are often involved in the mobilization of the community for clean-up campaigns.

C/ Women and youths: special roles in community-based solid waste management

1. Women

Women's cooperation is essential for the long-term success of any project concerning urban services. In many cultures, women are responsible for keeping the home and its immediate environment clean. So disposal of waste is one of their daily tasks. Furthermore, women are the first and foremost users of different urban services such as water supply, sanitation, waste management. This role of women makes them ideal beneficiaries of solid waste management projects. They usually give improvement of services a higher priority than men. Their voice is seldom heard and their participation in community decision-making is minimal. Women may not only be interested in solid waste management projects as a provision of a service but also its employment and income generating aspects may interest them. What experiences appear in the literature on community-based solid waste management projects? What is the role of women there? What are their specific problems?

Women's participation can take the following forms:

1. Women are often the initiators of a solid waste management project or of general improvement in solid waste management.

2. They carry out education campaigns on sanitation behavior, preventive health, environmental problems, etc.

3. They are sometimes involved in the management of the system.

4. They operate and manage a solid waste service as members of a micro-enterprise. Micro-enterprises for waste collection, street sweeping, etc. are often dominated by women.

5. They exercise political pressure on local governments.

6. They act as watchdogs of the community.

Different studied reported that problems encountered by women in community-based solid waste services concentrate on under representation in management committees and work in operation that is physically heavy.

2. Youths

In some cases, young people play a special part in solid waste management too. Children often help their mother with her daily tasks such as bringing waste to the communal collection point. Unemployed adolescents discover the income-generating potential of solid waste services. They can earn extra points in the sports league with these activities. One problem related with the involvement of young people in community-based solid waste services is the youths want a material reward for their participation or management efforts.

10.4. Organizational structures of community-based solid waste management

Many different configurations of community-based solid waste management organization exist. This chapter describes three common organizational structures.

1. Micro-enterprises and community based organizations working together

Cooperation between micro-enterprises and community-based organizations is not uncommon. Micro-enterprises are cooperative enterprises with eight to twenty-five members who share responsibilities and income and who operate together a waste collection scheme, street sweeping, etc. Sometimes members of a micro-enterprise live in the neighborhood where they operate a service, but this is not always the case. They are included as part of community management only, when the service is somehow controlled by community members. Community-based organizations are organizations that derive their members from and operate in a specific neighborhood (or village, in a rural context).

These two groups of people may work together to manage and operate a solid waste service in a neighborhood, sometimes with separate objectives. A community based organizations usually works more from the perspective of a clean neighborhood, a micro-enterprise will generally focus more on its income generating aspects. Generally the community based organizations has management and supervision tasks, while the micro-enterprise is responsible for operating the service.

2. Governmental institutions assisting community based organizations

Another possible organizational structure of a community-based solid waste service is the involvement of governmental institutions assisting community based organizations. These institutions may be the governmental agency responsible for solid waste management or, which is more common, the local governmental authorities, either administrative bodies or government-led development committees. Usually these governmental institutions have relatively much autonomy towards the central government and their motivation comes from their need to control all community services. They are usually involved in the overall supervision of the solid waste service, but in some cases their participation extends to financial control or technical support, e.g. the provision of a refuse collection vehicle. In this organizational structure, operation and management of the service are carried out by several community based organizations, either motivated by the generation of income or by the interest in a clean neighborhood.

3. Combined NGO- community based organizations efforts

Community-based solid waste services can also be managed by a cooperation of non-governmental organizations (NGOs) and community based organizations (CBOs). The clearest difference with CBOs is that NGOs usually operate on a larger geographical scale, at city, regional, national or even international level. NGOs usually set up community-based solid waste management as a development project and only in operating and managing these services they work together with CBOs. The role of NGOs is confined to overall supervision, but very frequently it also includes financial assistance and control, training and recruitment of management committee members and of operators, and other technical support. CBOs play several roles in operation and management, such as in the cooperation with governmental institutions.

10. 5. Social and management problems of community-based solid waste management

This section gives an overview of the social and management problems encountered in community-based solid waste management projects. The problems have been classified into five categories: low participation of households, management problems, social operation problems, financial problems and failing cooperation with municipalities. Each category has been divided in two to five subcategories, which correspond to more detailed descriptions of the social and management problem of community-based sold waste projects. At the end of each paragraph an overview is given summarizing problems and solutions of that category.

A/Low participation of households

1. Low community priority for solid waste management

It is not uncommon that low-income neighborhoods often face considerable problems. Inadequate solid waste management is just one of them and its improvement may not have priority for a community. If solid waste management is not a felt need, this will have consequences for their participation in the service and their willingness to pay.

A possible solution to the problem of lack of community priority for solid waste management is education. Another solution involves consultation with the community on its problems and priorities. A more comprehensive community needs assessment study may also lead to a better designed project.

2. Low willingness to participate in collection and recycling

Households often behave contrary to schedules and rules of effective solid waste management. Sometimes this is caused by a lack of facilities; if a transfer point or dumping site is more than 100 meters away from their house, people tend to throw their waste much more often in streets, open spaces and rivers. More often, however, it is due to households lacking knowledge and incentives to keep to the rules of the collection system, and operators lacking sanctions and authority.

Low willingness of households to participate in collection and recycling also depends on the perceived benefits and costs of the system. In some countries, servants, caretakers and watchmen are important agents in waste handling: they bring the waste to communal bins, keep certain items apart, and so forth. These servants are known to be unwilling to cooperate in separation at source, both because they know the value of the recyclables and do not want to sell them to waste collectors , or because they do not like the extra work.

A solution for this problem is servants and/or watchmen were given a certain benefit and thus integrated into the system. The implementing NGO, a women's organization, tried to encourage housemaids to engage in recycling by giving them proceeds of the sales of recyclable materials. This is just one example of the provision of appropriate incentives to increase the participation of community members in a solid waste management system.

3. Low willingness to keep public spaces clean

In several cases it is mentioned that residents of a neighbourhood have a sense of responsibility for their home and immediate environment, but that public spaces such as streets and drains are considered the responsibility of the state. Often municipalities lack the money and/or manpower to fulfill this task and sometimes they think the neighbourhoods are responsible for this. This has negative consequences for the cleanliness of public spaces, and for the willingness to pay and the behaviour of households. Periodical clean-ups may have a temporary positive effect on the cleanliness of streets and public spaces. With a lack of social cohesion and control in a neighbourhood, this is not a sustainable solution. Especially in low-income neighbourhoods cooperation may be difficult, because of the high mobility of households and the large amount of renting people. Moreover, urban problems are known to be personal and coping strategies individualistic.

4. Low willingness to pay

Willingness to pay is a rather central point, because it is important for the success of a community-based solid waste management project and it is related to many other aspects such as the motivation of operators and households and the reliability of the service. Community perception of fees and of the waste collection service is essential for its willingness to pay. If residents think they already pay for collection through taxes, or if they do not trust the service, they refuse to pay.

The service must be reliable to sustain willingness to pay. Payment according to achievement may be a solution, because households receive an observable benefit. A change in the way of payment might improve willingness to pay.

Education campaigns as part of community-based solid waste management are both inadequate and inappropriate. Inadequate in the sense that before and during operation of the service education campaigns are often absent. Inappropriate, because the contents of educational material is often not suited to the interests and priorities of the community.

The experiences also prove that education is needed to maintain community participation, to establish a 'spirit of responsibility' towards environmental problems and the most suitable ways of dealing with them. Moreover, it is necessary to inform households about the benefits and practice of separation at source, the benefits and schedule of collection, the tasks and responsibilities of households (time and place to deliver the garbage) and the ways of payment.

Table10-1. Participation problems in community based solid waste management

PROBLEMS	SOLUTIONS	EFFECTS
low community priority for solid waste management	-education -provision of appropriate incentives -consultation with the community -give community a role in planning -community needs assessment study	-on its own inadequate to change priorities and needs -more appropriate system, based on real priorities and needs
low willingness to participate in collection and recycling	-household and city competitions -pay households for their participation -exchange garbage for free	-effective -effective

	bus tickets or food parcels -give proceeds of recyclables to servants -education	-effective -on its own inadequate to change behaviour
low willingness to keep public spaces clean	-periodical clean-ups -education and make site valued -integrate street sweepers in solid waste management system -guard at transfer station -shared caretaking systems	-effective
low willingness to pay	-change way of payment -education	-way of payment: *with water bills: success unknown *with electricity bills: failed *as a lump sum: successful -on its own inadequate to change willingness to pay

10.5 2. Management problems

A/Low willingness to manage

Management of community-based solid waste services is often a voluntary activity, mostly carried out by the more effluent residents, who are motivated by community benefits such as a cleaner environment, a better health of neighbourhood residents, status of the job, etc.

B/ Lack of accountability to the community

Lack of accountability to the community depends on the management structure, the way of supervision and the links with the community. A way to improve accountability to the community in general is to write down agreements on rights, responsibilities and obligations of the waste services system. These may involve the obligation to report regularly to the neighbourhood committee or to community members, a bulletin board about financial affairs, and meetings with neighbourhood committees about the quality of the service.

C/Unrepresentative management

The accountability to the community of the managers of a solid waste service also depends on the composition of the management committee. Whether it is an elected body or appointed by the local government, whether it consists of traditional leaders or modern community organizations, or of influential individuals. This determines the degree of representation of different community interests in the management committee and its responsiveness to community needs. Representation of the interests of under-privileged groups or minorities is particularly important for women, youths and certain cultural or ethnic groups.

Table 10-2. Management problems in community based solid waste management

PROBLEMS	SOLUTIONS	EFFECTS
low willingness to manage	-restructure management committees -training and exchange visits for management committees -technical/financial/moral support from the municipality	
lack of accountability	-define rights, responsibilities and obligations -establish procedures of control	-only successful if effectively enforced
unrepresentative management	-intervention of implementing agency to adjust composition of committee -by-pass existing committee/work directly with beneficiaries	-may adjust composition of committee -more effective participation

Source: Adapted from Ref.8

10. 5.3. Social operation problems

A/ Low salary of operators

There is a difference between remuneration of operation and of management of community-based solid waste management projects. Operational activities (collection of waste, sorting, recycling) are almost entirely done on the basis of profit, i.e. a personal salary, because the work is hard and status is low.

The salary of operators of waste collection services is often low, because waste collectors derive their income from waste collection fees and from the sale of recyclables. Both do not yield much revenue in low-income neighbourhoods. Fee collection is not high, because households in low-income neighbourhoods are not able to pay high fees. The waste that remains to be collected is often worthless due to its high organic content. Another reason for the low salary of operators of waste collection services is the size of coverage areas, which is often too small to earn an adequate income.

Some projects have `solved' the problem of low salaries by employing people part time. This leads, however, to a weak bargaining position for the manager(s) and to a less reliable service, because waste collection as a side job will no longer be a priority for the people operating the service. On the other hand, it is clearly an incentive for operators that they can use their equipment and time for other activities.

Another possible solution either by serving different income groups or by serving different generators of waste (households, industries, commercial business, institutions). Different groups can be asked different fees. This increase in the coverage area and in the number of customers can provide the operators with extra income.

B/ Low status and bad working conditions

The low status of waste collectors may be caused by their low salary, by the nature of their work and sometimes by their waste-picker background. Low salaries were already explained above. The nature of their work is often considered unpleasant and filthy, not only collection but also activities such as sorting of garbage at a composting plant. Especially in India some richer households have problems with waste collectors who have formerly been waste pickers. They are suspicious of them, sometimes accuse them of theft and do not agree that they have a legitimate role in their neighbourhood.

Solutions for the problem of low status are: education of households by volunteers from the area, promotion campaigns, a letter of authority from the municipality to the households, identity cards are given to the waste collectors.

C/Unreliable service

An unreliable service, which does not arrive in time or is not carried out according to the expectations of the community, has consequences for the trust of the community, for their participation and willingness to pay for the service. It may be caused by a lack of performance control, a lack of priority of the service, when waste collection is carried out as a part time job. If operators have formerly been waste-pickers, they may cause additional reliability problems. These people, used to the freedom of the street, are sometimes difficult to train to perform a reliable service.

Involvement in decision-making appears to be an incentive for operators to perform better. In Bolivia, for example, members of micro-enterprises have a higher labor productivity and morale than the employees of municipal services, who collected garbage before, because they are owners-operators of the system and because they are paid according to achievement. A solution born out of necessity to improve the reliability of the service is to relate payment of operators more strictly to performance. This was applied in Chad, where households started to pay waste collector per round instead of per month. In Indonesia the problem of reliability was solved by a different division of collection areas and responsibilities.

D/ Competition from private entrepreneurs

Some projects in India working with ex-waste pickers suffer from problems with their former employers, waste traders, and with private waste collectors. In Pakistan, the new community-based waste collection system disrupted the sweeping areas of municipal sweepers who used to collect valuable garbage there in their leisure time. In Metro Manila, the Philippines, in the late 1970s a project was started by the government that totally by-passed the existing informal waste collection and recycling system.

E/ Space problems

Space is an important constraint for all composting and sorting/recycling projects. A project in Vila Reis, Brazil, has temporarily stopped its activities, because it has to arrange for a deposit site for recyclables in order to gather enough quantity to sell it. In some quarters there is no space for communal bins because of the high population density.

Consultation with local NGOs and opinion leaders to find sites for sorting and composting appeared to be an effective solution in Ghana and Cameroon . Next to negotiations with quarter heads, a massive media campaign with the help of local youth groups was used in Cameroon to solve this problem.

10**-3. Social operation problems in community based solid waste management**

PROBLEMS	SOLUTIONS	EFFECTS
low salary of operators	-part time employment -cross-subsidies -add income generating recycling projects -provide group benefits -provide exemption from certain municipal taxes	-less reliable service/poor bargaining position management -effective -effective
low status and bad working conditions	-education/promotion campaigns -identity cards for collectors -municipal letter of authority -official introduction of collectors by NGO -provide operators with facilities	
unreliable service	-involve operators in decision-making -relate payment to performance -different division of collection areas and responsibilities	-too small areas/too small returns

competition of private entrepreneurs	-consultation with municipality or governmental agency -education of households -integrate private entrepreneurs into the project	-no willingness to intervene -mixed results
space problems	-consultation with local NGOs and opinion leaders -start a media campaign with the help of local youth groups -delegates from neighbourhood lobby municipality for space	-effective -effective

Source: Adapted from Ref.8

10.5.4. Financial problems

A/ Cost recovery problems

Cost recovery problems refer to a lack of funds to cover capital and recurrent costs of solid waste activities. Lack of funds can be caused by inadequate fee collection, too low fee rates, failing fund raising methods, low loan repayment, difficult access to credit, and marketing problems. In many cases, fees for community-based waste services do not cover costs, because they are fixed by the government and do not take into account costs and taxes that have to be paid by the community service.

Cost recovery may be improved by offering additional services. In Ivory Coast the solid waste collection service ran into financial difficulties because of low willingness to pay. They started offering extra services such as cleaning bathrooms and toilets. A possible solution to the repayment problem is tighter financial control, which includes effective book-keeping practices. Some sense of responsibility towards the communal fund has to be established and some kind of sanction has to be thought of. In Egypt, for example, small credit groups of women who are responsible for repayment of each member of the group, give a high repayment rate through social control.

Marketing problems can be avoided by conducting a socio-economic feasibility study before implementing the project. In Mali, micro-enterprises involved in solid waste collection have experience with this kind of studies.

B/Inadequate fee collection

Fee collection for solid waste services appears to be influenced by willingness to pay, by the way of payment, by the availability of sanctions and by the persons collecting fees. If willingness to pay is low, fee collection will be low too. Lack of sanctions and a lack of legal obligations to pay are often the cause of fee collection problems. The way of payment, i.e. the way fees are collected, differs: sometimes garbage collection fees are paid once a month or a week, sometimes per round. Fees can be collected by special persons, fee collectors, or by the garbage collectors, or during social meetings. Not only the type of persons collecting fees is important but also the way they are motivated for their job, their incentives.

Inadequate fee collection can have negative consequences for the motivation of garbage collectors and thus for the reliability of the service, if they depend directly on these fees for their income. Low reliability of the service can lead to low willingness to pay of households. It thus may become a vicious circle. One way to improve fee collection is to change the way of payment. In Gedaref, Sudan , garbage fees are paid on top of the sugar price, and are collected through sugar distribution. The community has been consulted upon and agreed with this way of payment. In La Paz, Bolivia, the municipality tried to collect garbage fees with electricity bills. This was not successful, because the people were not informed properly. It even came to boycott actions. Garbage fee collection together with water bills was tried in Indonesia. Results are still unknown. In Surabaya, Indonesia, a minimum fee was set during a meeting with residents. This fee covers all social welfare activities in the neighbourhood, and it is collected during monthly social meetings. This system is rather effective because people prefer to pay one lump sum instead of many small amounts. Because success of a certain way of payment usually depends on the local context, community preferences have to be assessed. Another way to improve fee collection is to give fee collectors more personal benefit. In Ivory Coast , collection team members receive 80% of the fees they themselves collect. First everybody received 80% of what the whole team collected, but that appeared to be not a high enough incentive.

A subject that is often neglected by community-based solid waste management projects is the possibility of sanctions for non-payment to increase fee collection. In Padang, Indonesia , it is practice to pay the solid waste fee directly to the garbage collectors in the beginning of the month. Otherwise one's garbage is not collected. In other Indonesian projects in Surabaya the following sanctions were applied: denial of official documents, letters of approval, licenses, etc. These sanctions are possible as these projects are implemented by local administrative bodies.

As was made clear above, the persons collecting fees may influence the rate of fee collection. Fee collection by operators rather than government officials appears to be more effective. A different but equally effective option is fee collection by respected community members, as applied in Mali. Respected senior persons from each concession (group of households) hand over the money to the collection crew.

C/Low ability to pay

Low-income communities are often assumed to have a low ability to pay for services. Not all service levels are affordable and high fees cannot be charged. In Mali, COFESFA experienced this, when this micro-enterprise wanted to collect cost covering fees from households. It appeared that they could not afford the required fees. In Panaji, India, they solved this problem by introducing different fees and different collection systems for different generators of waste. Households pay a low fee and bring their garbage to communal bins, which are inexpensive to empty. Clinics, restaurants and hotels, etc. were charged a higher, cost covering fee for door-to-door collection.It underlines the fact that it is necessary to study willingness to pay beforehand, as well as which system and rate of fees the community prefers.

Next to variable fees, cross-subsidies are a way of dealing with difficulties with ability to pay. In some Indonesian projects fees are based on the amount of garbage and/or on the income level of the household. Cross-subsidies can be established by defining waste collection areas that are mixed in terms of income levels and/or waste generators. This may be a way to avoid political problems.

Table 10-4. Financial problems in community based solid waste management

PROBLEMS	SOLUTIONS	EFFECTS
cost recovery problems	-improve financial control -offer additional services -carry out a socio-economic feasibility study	
inadequate fee collection	-change way of payment	-mixed results
	-give fee collectors more personal benefit	-effective
	-establish/enforce sanctions for non-payment	-effective
	-fee collection by operators rather than government officials	
	-fee collection by respected community members	-effective
low ability to pay	-different fees for different waste generators and levels of service -base fees on income level and/or amount of garbage produced	

Source: Adapted from Ref.8

10.5.5. Failing cooperation with municipalities

A/Direct obstruction of community-based solid waste management

A municipality or solid waste agency can also obstruct community-based solid waste management in various ways, either directly, by hampering the performance of community-based services, or indirectly, by refusing to provide legal, financial or promotional support. In this paragraph attention will be paid to this direct obstruction, of which the bad coordination between primary and secondary collection is one of the most cited examples. Sometimes municipalities seem to obstruct the operation of community-based services unwillingly, simply due to a lack of knowledge, for example, when they do not take into account the effects of changes in the secondary system on community-based primary collection schemes

One of the most frequently encountered problems in community-based solid waste collection projects is accumulation at communal collection points, the temporary dumping sites from which the municipal cleansing department is expected to remove the garbage. The schedules of primary and secondary collection are often not coordinated; municipal secondary collection is irregular and insufficient. Examples are Burkina Faso, Ivory Coast, Mali and India. In South Africa it was the private company, contracted by the municipality to bring the waste from transfer sites to the final disposal site, who performed badly in this respect. This kind of problems are usually caused by a lack of means, equipment as well as finances. But more structural is the inability or unwillingness of municipalities to adopt a clear solid waste management policy and a strategy to integrate community initiatives into the whole solid waste management system.

Coordination problems between secondary and primary collection are part of larger communication difficulties between communities and municipalities. An ad hoc solution to the problem of bad coordination is to bring the waste directly to final disposal sites yourself.

A more structural approach includes better communication between communities and municipalities, for example via meetings between representatives of the community and the municipality, right from the beginning of a project. This approach is tried in Sri Lanka in housing and upgrading programmes.

B/Lack of assistance from the municipality

Municipalities can assist community-based solid waste systems in different ways. One manner is the provision of facilities (equipment, composting sites, etc.), others are the establishment of legislation, financial assistance, promotion. Sometimes a municipality plays a highly positive role in stimulating community-based solid waste management. Quito offers an example: the municipality stimulates a neighbourhood sorting and recycling plant by doubling the sales of recyclables. This money is invested in local projects, selected by the community. The attitude of the municipality is, however, often bound to elections, its assistance is thus temporary and its solid waste management policy lacks continuity.

Absence of legislation backing up community initiatives in solid waste collection and recycling is a common problem. For example, laws to oblige households to separate their wastes at source, or to make garbage ready for collection on certain days in the week, legal sanctions for non-payment of fees and laws to prohibit free discharge of garbage into rivers, streams, etc.

Community organizations that have proved their capacity to achieve visible improvement are often able to convince the municipality of the need to help them. But this depends also on political circumstances.

Table 10-5.Cooperation problems with municipalities in community based solid waste management

PROBLEMS	SOLUTIONS	EFFECTS
direct obstruction of community-based solid waste management	-improve communication with the municipality -extend the service to include secondary collection	-not always possible
lack of assistance from the municipality	-mobilize the community to lobby for assistance from the municipality -local authority involvement from the start -structured facilitation of formal-informal cooperation	-effective -effective

Source: Adapted from Ref.8

In summary community participation in solid waste management may take different forms or levels. Community management is one of them. Real community management, involving all three aspects of responsibility, authority and control mentioned in the Introduction, is not very common in solid waste management in urban low-income neighbourhoods. Local leaders, formal and informal, women and youths often have special roles in community-based solid waste management. Organizational structures differ, depending on locally variable partnerships between different agencies. As a rule, in community management of solid waste management, there is an active community-based organization, an existing CBO or a newly established one.

The most important social and management problems faced by community-based solid waste management projects appear to be motivational issues and cooperation with municipalities. Motivational issues refer to the motivation of participating households and their servants, of operators and managers of solid waste services. They have crucial roles in the functioning of the service. These groups are all affected by the low status of waste and its dirty image, resulting in low willingness to participate in recycling and collection, unreliable service, and low willingness to manage. Education appears to be an inadequate solution for these problems. Education alone does not seem to be enough to change the behaviour of households or to increase their willingness to pay. Moreover, it has to be tuned to the benefits of the solid waste service as perceived by the target community.

Another major problem is the failing secondary collection, which can undermine the motivation of the community undertaking primary collection. Bad coordination of primary and secondary collection, illustrated by accumulated garbage at transfer stations, is a problem that is mentioned by most community-based initiatives. The bad performance of the municipalities in this respect is rooted in a lack of funds, inappropriate equipment, inefficient management, and unskilled personnel.

Other important managerial problems are those related to financial issues, because these determine reliability and sustainability of a service for a major part, notably inadequate fee collection and lack of sanctions for non-payment.

10.6. Review Questions

1. Explain who should take the initiative for the solid waste service?
2. Mention with which incentives are households stimulated to participate?
3. Describe which factors determine willingness to pay for a solid waste service?
4. Mention the role of women in community-based solid waste management projects.
5. How can cooperation between formal and informal leaders be improved with regard to community based solid waste management?

CHAPTER ELEVEN

PLANNING OF SOLID WASTE MANAGEMENT FACILITIES

11.1 Learning objectives:

At the end of this chapter students will be able to

1. explore some of the important considerations in the planning process,
2. describe what constitutes waste management programs and plans,
3. define a general methodology for planning and the preparation of planning reports,
4. examine the nature of the decision-making process in the field of solid waste management.

11.2 Introduction

Recently, it has become better known that the Earth faces several environmental challenges such as acid rain, ozone depletion, climate change, loss of biodiversity, toxic and hazardous waste, and pollution of water to name a few. These problems lead to a more limited accessibility of natural resources, which support human activities and economies. Therefore, it is not surprising that in recent years the environmental concerns have become economic concerns as well. However, looking at the current economic and market conditions and attitude such as the rapid exploitation and inefficient utilization of resources, there are only few signs of hope to change the present attitude towards a more sustainable one. Nevertheless, the local and global crises of the society and the economy underscore the importance of shifting towards sustainable development.

The concept of sustainable development was drawn up in the Brundtland Report in 1987 defining it as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The interdependency of the environment and development was highlighted, and it is also well known fact that without comprehensive action, further development cannot be reached. Thus, the concept of sustainability forces us to look at the environmental problems in conjunction with the existing economic and social orders and problems.

The UN Conference in Rio in 1992 addressed among other issues, the reduction and elimination of unsustainable patterns of production and consumption since it is no longer possible to deplete non-renewable resources or to dispose of waste at such a rapid rate as is done at present. However, the creation of wastes has been one of the distinguishing characteristics of every human society. Waste generation is also an indicator of how efficiently a society uses raw materials, since waste represents the loss of both material and energy resources. It is therefore crucial to reduce the load on the environment and to develop a closed-loop handling of materials in order to attain long-term sustainability.

The first step towards a more sustainable waste management system is to break up the linear material flow and to close the cycle. Need to become more circular and reduced in size. They further argue that products should be more durable and when their initial use is over, they should not be disposed of, but rather repaired or recycled utilized as resources for other production processes.

The creation of integrated waste management systems is a new trend brought about by past environmental damage from landfills, scarcity of land near urban areas, and growing public opposition to landfills and incineration plants. The integrated waste management systems depend on a combination of different waste treatment methods to minimize the dominance of the landfill sites. Therefore, the integrated waste management system can, to a large extent, contribute to achieving sustainable waste management.

11.3 Planning in solid waste management

Planning is an important first step in developing public understanding of the need for solid waste management facilities. Setting a facility is an emotional process, creating strong public reactions to perceived environmental problems. Permits are required at most facilities, and permitting is a time- consuming process.

Planning in the field of solid waste management may be defined as the process by which community needs regarding waste management are measured and evaluated and workable alternatives are developed for presentation to decision-makers. Planning is accomplished by applying the engineering principles to the needs, capabilities, and goals of the community. Planning in the field waste management is both exciting and challenging, because most of the technical, environmental, economic, social, and political factors, and the interrelationships that are involved.

Important considerations in the planning Process

Integrated solid waste management encompasses a wide range of individual activities, which must be combined in such a way that the public, politicians, decision makers, and planners are able to recognize and understand the important relationships in the planning process

In general terms, the planning process involves the collection, evaluation, and presentation of data relevant to some problem. In the field of solid waste management, the problem usually requires some type of action by a decision maker, who probably is and elected official. Therefore, to understand the nature of the planning process in this application, it is important to consider

1) the framework in which planning activities are usually conducted,
2) the effect of planning,
3) the jurisdictional levels at which planning studies are conducted,
4) the impact of alternative concepts and technologies on the planning process, and
5) the definitions of programs and plans.

Framework for Planning Activities. Planning activates in the field of solid waste management are generally undertaken in response to the recognition of some community need. In some instances a community may prepare a plan because it is mandated by state or federal government.

The planning activity commences once a community need has been articulated and the problem has been recognized. Problem recognition is important, because if meaningful planning is to result, it must be related and is on little value. It is the responsibility of the planner, however, to call to the attention of the decision-maker all the potential problem areas that may be identified during the planning process.

At the same time as the problem-solving cycle moves forward, there is feedback from the community to the decision-maker and then to the planner. In Fig 11-1, feedback terminated at the planning activity, because it is assumed that the true problem is being dealt with. In cases where incorrect definitions are select, the feedback loop would extend to problem recognition, and a redefinition would be necessary. The presence of feedback in the problem-solving cycle is essential to the development of responsive management plans.

In cases where a state or federal mandate requires a plan, such as mandated waste diversion goals, it is necessary to add a monitoring activity to the framework, Referring to Fig, 11-1 , monitoring would be apart of community need.

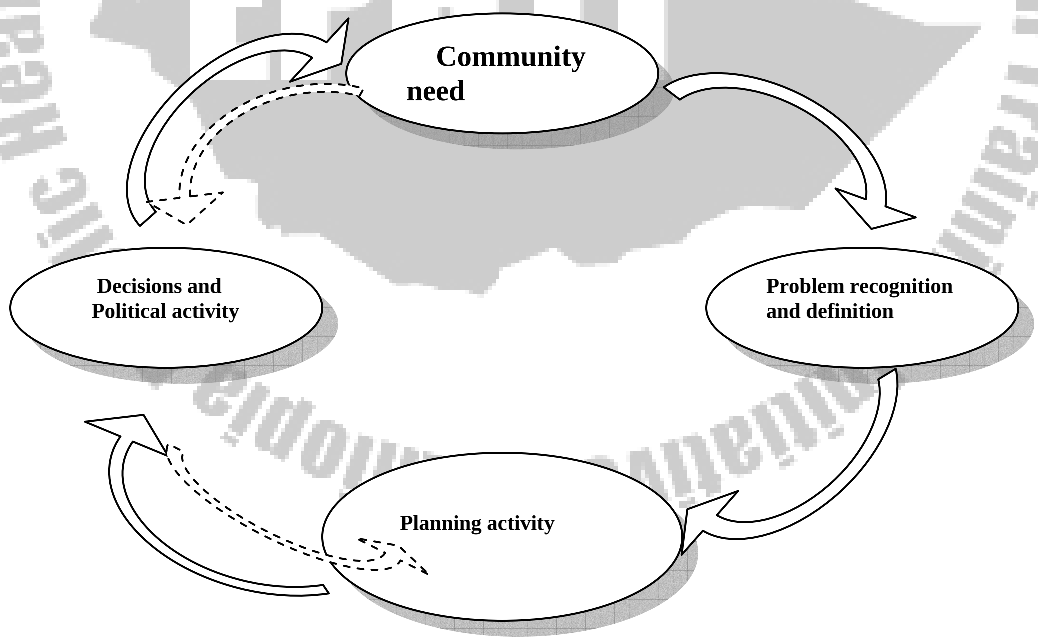


Figure 11-1 The community problem-solving cycle and the interrelationships of planning that are involved

Source: Adapted from Ref.6

A community need is identified by the public, usually in response to issues related to costs. Services being provided, resources utilization, and environmental protection. The extent of the need is often determined by the social standards of residents, institution, and businesses

Problem recognition and definition: Responsible decision-makers perceive and interpret community needs. They also are responsible for problem definition and specification.

Decisions and political activity: This is the action step in the problem-solving cycle. Decision-makers review alternatives; select alternative to be implemented; and make financial operation, and political decisions.

Need, with the results of monitoring being compared to mandate diversions goals and any shortages considered a sign of a problem. The plan would be revised to correct the problem.

Planning time Periods: Planning for integrated solid waste management can be either short-or long-term. A precise time division is not fixed, although five to seven years into the future is accepted as the upper limit for short-term planning; long-term planning extends for all time periods.

One difficulty that arises in selecting an appropriate time period for planning us that while short-term planning may be limited to five to seven years, the payback period for equipment and facilities may be considerably greater, often running to 20 years or more for such facilities as municipal solid waste combustors used for waste transformation. When energy recovery options are being evaluated, long-term information is available on the useful life of such facilities. The lack of information can have serious implications on the economic feasibility of energy options. In situations in which the uncertainty is high and long-term payback periods are required, the best approach is to develop multiple analyses, based on estimates of both average and least optimistic conditions. The results of multiple analyses, which can be used to prepare a sensitivity analysis, will give the decision-maker a better understanding of the risks involved. Also a planner will seldom be questioned if the process performs better than anticipated.

Planning levels. Planning activities for integrated solid waste management can be associated with three jurisdictional planning levels:

(1) Local,

(2) Sub regional or regional and

(3) State or federal.

The characteristics of these three levels are identified in Table 11-1. The distinctions are sharpest between the firs two planning levels. Local agencies usually find responsibilities for management fragmented among many organizations. Economic resources are usually dispersed widely at the local level and are unavailable for effective planning and plan implementation.

By contrast, at the sub regional and regional planning levels, the political and social awareness of waste management has caused several agencies to join forces to achieve a common goal. Joint objectives are worked out, along with estimates of the economic resources necessary to develop compressive plans.

In the broadest sense, all planning is based on predictions of future conditions. Developing concepts and technologies for integrated solid waste management are based on new ideas derived from the public's awareness of resources, economics, and the quality of the environment. Typical developing concepts include reuse of food containers, limiting of product packaging containers, control energy-demand products.

Planning for Emerging concepts and Technologies. Engineers and planners in the field of solid waste management today are confronted with breakthroughs both in public awareness and in technological advancements that make comprehensive planning for the future as especially difficult task. Many of the recent technological advancements are for waste diversion and are as yet too new to have been proved in full-scale instillations. Thus, decision-makers are often faced with a choice of whether to use long-established and well-proven equipment and techniques, which may or may not be the optimum for present and future conditions, or to use new and unproved technology, which may or may not work as expected.

Programs and plans

In general terms, programs and plans represent blueprints for achieving solid waste management objectives. The fundamental difference between programs and plans is in the scope of activities involved.

Programs. As used in this text, the program encompasses all the activities associated with the solution of a problem within functional element of an integrated solid waste management system. Thus, typical program areas of concern within a functional element may involve operation budgets, financing, rate structures, staffing requirements, contracts, equipment procurement and replacement and maintenance.

Plans. Solid waste management plans are developed to define and establish objectives and polices. Typically, a plan will encompass one or more functional elements. Most plans are made up of many programs. And each program may be considered individually during the development of a final plan. For example suppose that a draft plan has been developed and is being reviewed in public hearings. If objections are raised to the plan. They can now be isolated with respect to the individual programs. By focusing on an individual program, it usually will be possible to reach a workable compromise without having the entire plan rejected. In fact, this is the decision- making process.

In many planning situations, it is beneficial to identify more than one program or set of programs that can be used to solve a given problem- in other words, to develop alternatives. Alternatives are used as a means of demonstrating the impact various programs on the solid waste management system. They serve only as an aid to the decision-maker in understanding the impact of management choices described in a waste management plan. Often, a preliminary plan is developed in which two or more alternatives involving several programs are presented to decision- makers, and the final plan adopted is in fact composed of programs taken from one or more of the original alternatives.

Planning Study Methodology

In most cases the planner and the decision- maker do not have an opportunity to study the entire solid waste management system and develop a total knowledge of the community under all conditions. Time and economic constraints resulting from social and political needs often lead to decisions based on little or no information. For planners and decision-makers to respond on these situations and to ensure that the best use is made of time and available funds in the resolution of solid waste management problems, the following step-step planning procedure is recommended.

Step1: Problem Definition and specification. The first and most critical step in any planning study is to obtain a clear problem statement and corresponding specifications from the people responsible for making decisions about solid waste management. Problem statement and specifications usually are derived from the concerns of the public

Difficulties often arise because solid waste systems are not well understood at most levels of decision making. Consequently, the planner may have to redefine a problem that was originally specified by a decision-maker.

Step 2: Inventory and Data accumulation. In this **step** an inventory is made of all pertinent factors about the community, and data are collected as needed to meet the problem specification s. the main purpose of the inventory is to define the existing solid waste system(s) as completely as needed and as accurately as possible and to collect certain other basic information (such as population data)- a task that requires a considerable amount of judgment. It is an important step in planning, because all subsequent recommendations for action will be asked on the findings of this step. Therefore, it is essential that all of the functional elements that make up an integrated solid waste management system be considered at any level of planning.

Step 3: Evaluation and Alternatives Development. This step involves the detailed evaluation and analysis of the data accumulated in Step 2. It is during this step that the programs of the plan beginning to be formed. In some cases, it may be necessary to collect additional data and information. However before the programs are formed, it is important to review the original problem statement and specifications. Often it will be found that some revisions have to be made in light of the data gathered during the inventory.

Because a problem can have more than one solution, it is beneficial for decision-making purposes to develop alternatives composed of one or more programs. When practical, these alternatives should be documented for presentation in the plan. A simple plan may deal with only one or two programs. A more complex plan includes more of the functional elements, and its alternatives may include numerous programs. In either case, both administrative and engineering activities must be evaluated.

In developing alternatives, it is especially important that all functional elements be coordinated to ensure and integrated system from onsite storage through processing and final disposal. By evaluating the coordinated programs, the planner is able to recommend viable alternatives.

Step 4: Program and Plan Selection. In this step, a limited number of alternatives are selected by the planner for inclusion in the plan. The alternatives are reviewed by the planner, the decision-maker, and members of the public. The logic of the individual programs that make up the alternatives is reviewed, and programs are changed as necessary to include review comments. The admistrative control of all programs is identified and evaluated during this step. Administrative control is important, because integrated solid waste management will not function properly without responsive control. Hence the planner must develop a thorough knowledge of the social and political structure of the community.

The final action in this step is the selection of a preferred set of programs to form the plan. The programs can be selected from a single alternative, or they can be selected from various alternatives. The final selection will be made by decision-maker.

Step 5: Development of Implementation Schedule(s). When planning failures have occurred, the lack of a well- defined implementation schedule acceptable to administrative and management organizations has been principle contributing factor. The degree of documentation in any implementation schedule depends on the types of programs developed in the plan. If possible, the degree of documentation that will be required implementation should be set by the planner and decision-maker during the problem specification stage (step 1) of the plan development. Details and examples are presented in the case study at the end of this chapter

With the completion of Step 5 and proper documentation, the planner will have completed the most demanding work. The planner continues to be involved in the planning process as the plan is implemented and when the plan requires updating. The principal work for implementation shifts to the decision-maker.

The Decision Process

The purpose of planning has been established as the accumulation, evaluation, and presentation of data relevant to a problem that requires some type of action by a decision-maker. As such, the planning process is an important part of the decision –making process; thus the relationship of the planner and the decision maker is normally quite close during plan development. Decision-making needs and events, as related to the selection and implementation of integrated solid waste management programs, are discussed in this section.

Requirements for Decision Making. It is clear one of the fundamental and perhaps most important requirement for decision making is sound planning.

Another is an understanding of the goals of the community. Consider the community in which you live. What do you perceive are the solid waste problems that need corrective action? If these problems are put into the framework of the planning methodology described earlier, a decision regarding their solution should become possible when the results of the planning study are available. That is precisely the task that faces individuals with responsibility for selecting and implementing solid waste management systems. In addition, the decision-maker must use the results of planning to follow through with capital expenditures, work force allocations, and system implementation.

The availability of newly developing concepts and technologies, and the recent boarding of social awareness concerning solid waste management and the value of resources, make the decision-making process in this field very uncertain. Without the effective decision-making guides that result from good planning, many decision-makers respond to this dynamic condition by putting off any this type of activity is sometimes politically expedient, it is rarely responsive to community needs. A more practical approach is to develop a dynamic solid waste plan and an appropriate updating technique that will allow solid waste system to be modified as social values. Concepts and technologies change.

Important Decision Events. As previously described, planning is an activity that leads to the development of management alternatives. Decision making is an activity that results in actions to implement equipment and work force systems. Although it is dangerous to oversimplify the decision-making process, the following four decision events are considered essential in completing solid waste management actions:

1. Adoption of a solid waste management plan, including specific programs
2. Adoption of and appropriate implementation schedule
3. Selection of an agency or agencies to administer the plan and operate the system
4. Selection of staff and funding sources and means

It should be noted that all the decision events are required to initiate an action program. For example, administration, operation, and staffing are normally important the responsibility of local management. Thus, decision events 1 and 2 are most important at the local planning level. In the implementation of sub regional or regional plans, however, it is often necessary to create new staffs and funding sources. Thus, at these levels, all four events are important.

11.4. Developing a facilities plan

Plan development and selection action are the final steps in the management planning cycle, and implementation is the final result of decision making. Planning steps 1 and 2 (problem identification and inventory) provide the planner with data and information needed to finish the tasks in steps 3 (evolution and development of alternatives), 4 (program and plan selection), and 5 (development of implementation schedules).

The root problems in solid waste management are the inability of a community to ensure the diversion of waste from landfills and an inability to ensure that there is sufficient landfill capacity for waste deposal for those wastes that the are not diverted. Developing a plan requires the identification of the opportunities for diversion across all functional elements. To complete the identification of opportunities, it is necessary to complete an inventory of facilities and management activities within each functional element. It is planning steps 1 and 2 that the community will begin to develop the data to understand is generated, what quantity of waste can be delivered, and what quantity must be delivered to a landfill for disposal.

Many states have passed legislation that mandates waste diversion, and in those states the regulatory agencies have written detailed guidelines for development of integrated solid waste management plans. These guidelines present detailed methodology for inventory of the existing solid waste management system as well as presenting suggestions for diversion methods.

Although a state agency sets guidelines for the inventory of data and ultimately for demonstrating the viability of waste diversion using those data, it is the local community that must pay for its waste diversion and disposal system. It is in planning steps 3, 4 and 5 that details of facility type, size and cost will be developed and selected by the local decision-maker. Each of these steps is described in some detail, because regulations now available do not provide acceptable procedures for these activities. The primary emphasis in this chapter is to illustrate the various activities by means of a detailed case study.

Evaluation and Development of alternatives

Solid waste management programs are presented to decision-makers in the form of alternatives so that the decision-makers can make their own judgment on the probable success of each one.

Perhaps the most important requirement for an alternative is that it must be quantifiable with respect to equipment, disposal site, economics, and other considerations. And alternative can be as simple as specifying the details of one-person versus two-person collection crews, or it may be as complex as specifying landfill disposal of all wastes versus processing wastes at multiple stations and selling recovered materials to numerous dispersed markets. Documentation for each alternative, regardless of complexity, must encompass the following

(1) performance,

(2) economic analysis,

(3) impact assessment and

(4) administration and management and implementation schedule

Performance. Performance means getting the job done. The work force and equipment required to provide the level of service desired by the community must be specified. The details of performance will vary with individual communities, but significant details that must be identified include

(1) level of service,

(2) equipment reliability and flexibility,

(3) equipment and work force expandability, and

(4) program compatibility with other environmental programs (air and water) and with future changes in solid waste technology.

With these details established, it is possible to contrast performance functions of a recommended program with performance functions of alternatives without additional planning studies. Such comparisons are an important part in achieving plan implementation. The work products of performance analysis are tables listing the category and amount of labor, drawings showing sizes and layout of equipment and buildings, and performance specifications for the type and quantities of materials to be processed under the alternative.

Economic Analysis. Once the details of performance have been identified, it is important to analyze the economic impacts of each alternative. The analysis must include estimates of capital cost as well as of operating costs. The cost of an alternative normally will be expressed as an annual cost. When divided by the annual quantity of wastes handled, the cost can also be expressed as a unit cost. Unit costs, such as birr per ton, are often used to compare the cost-effectiveness of alternatives.

When cost estimates are completed, financing methods can be identified. Some of the available financing methods are reported in Table 11-2. A financial analysis must be made for each program alternative, but the details must be limited to those consistent with the planning level and available planning funds. The work products from economic analysis are tables listing capital and operating costs, Performa charts showing income, expenses, and cash flow for the period of time under study, and sensitivity analysis showing the economic impact of variations from the financial base case.

Table 11-2: Financing methods for integrated solid waste management systems

Financing method	**Characteristics**
Debt	
General obligation Bonds	Voter approval required; low interest cost; excellent marketability; primary source of revenue is the local general fund.
Revenue bonds	Voter approval required; moderate interest cost depending on project; do not affect local agency debt capacity; revenues available from user charges only.
Joint-power agency bonds	Voter approval required; moderate interest cost depending on project; a high potential for legal complication and issuance difficulty; revenues available from user charges or contract payments.
Nonprofit-corporation Lease back bonds	No voter approval required; high interest cost; a high potential for legal complications and issuance difficulty; revenues available for rental payments.
Nonpublic	No voter approval required; high interest cost.
Revenue	
Pay-as-you-go	No voter approval required; no interest costs; requires careful long-term planning so advance budgets are identified.
Leasing	No voter approval required; no debt restrictions; revenues obtained from current operating budgets.

Source: Adapted from Ref.6

The final objective of many financial analyses is the establishment of service rates-what the customer will pay for the service. Rates should be equitable and should reflect as closely as possible the actual cost of providing the service.

Impact Assessment. The programs of an integrated solid waste management plan will have an impact on a community in three ways:

(1) through changes to the natural environment,

(2) through involvement, and

(3) through a reordering of the community's socioeconomic structure.

An attempt should be made to make quantitative estimates of each impact Unfortunately, most planning and decision making must be completed without full benefit of these estimates, because the interactions of the natural environment, human environment, and socioeconomic structure are very complex and the monitoring of a community's massive resource system is very difficult.

Determining the impact of alternative programs requires information from community agencies and groups not normally involved in solid waste management, including business and environmental groups, regulatory agencies for air and water quality control, legislative bodies, and resources agencies. Information from such diverse sources will help to fill voids caused by unattainable quantitative estimates.

Administration and Management. The administrative functions and organizations for implementation must also be identified for each alternative. It is most practical for the planner to develop details of administration only for the short-term Planning period. Detailed administrative planning for the long term is meaningless, because changes can occur so rapidly in the solid waste management field. Managers who are responsible for operations during the short term will usually establish organizational policies and functions for the long term.

Program and Plan Selection

The development of facility programs and a plan is a major task in achieving effective integrated solid waste management. Before the plan is presented to the community for acceptance, it is first refined through agency and special-interest group review. The best way to gain acceptance of the plan is to obtain support of key community groups. Another way is to demonstrate that the plan is compatible with other community goals, such as urban renewal, industrial development, and parks.

Obtain Community Support. The most positive bases for support are the residents and businesses of the community. Their involvement can take place either during the development of the plan or during its implementation. A strong public relations effort will be needed to develop community understanding of the plan. Political support should be tested and developed during the planning study through the presentation of progress reports at regularly scheduled political meetings.This procedure removes the element of political surprise from plan recommendations-a wise approach, as politicians are the final decision-makers. Support must also be obtained from state and federal regulatory agencies. The surest means of obtaining their support is to include regulatory standards and controls in the plan. If a variance cannot be avoided, it should be discussed fully with officials of the appropriate agency before the plan is adopted.

Demonstrate Compatibility with community Goals. The solid waste management programs must be compatible with other community goals. Generally, the higher the level of planning, the greater the need for compatibility. These other goals include land-use Zoning goals, environmental goals, and state and federal goals.

Because solid waste management activities are highly visible, all programs must be compatible with community goals as expressed in general plans and land use Zoning. All programs must also be compatible with environmental goals, which are generally community-oriented but might extend beyond community boundaries (for example, leachate movement in surface streams). In most cases, an environmental impact report is required at the time of implementation. Many agencies provide such reports as a part of plan development.

State and federal agencies are taking a greater interest in resource and raw-material depletions. As legislators are passing laws to mandate diversion of solid waste from landfills, they are also considering laws that favor use of the materials in solid waste as a resource in consumer products. The waste management system planner should monitor such interest and should make the community plan compatible where it is economically feasible to do so.

Development of Implementation Schedules

The primary objective of an implementation schedule is to set a time sequence of actions and to establish an organization structure to take action. The time sequence is normally divided into short-term and long-term actions. Other elements important to implementation are fiscal management and administrative considerations (regulations and standards).

Organization. The term organizational structure refers to the agencies legally responsible for performing the tasks set forth in the recommended plan. A logical split of organizations is by functional activity. Thus, both administrative and operational agencies must be defined in the implementation schedule. Typically, implementation responsibilities are split among several agencies, including departments such as public works, health, community development, and resources management.

Fiscal Management. The implementation schedule must also contain the following details of fiscal management:

(1) capital formation,

(2) cash-flow requirements, and

(3) revenue programs such as rates or taxes. An important part of fiscal management is the establishment and Maintenance of equity among these paying for the recommended program. The matter of equity becomes more difficult to settle as solid waste systems become more difficult to settle as solid waste systems become more complex-especially as resources are recovered and sold.

Regulations and Standards. Regulations and standards are the means by which system performance is measured and control is maintained. A time sequence, within which designated agencies will establish ordinances, standards, and other means of measurement and control, must be included in the implementation schedule. Standards for waste diversion are a recent requirement to be met in waste management plans.

Plan Review and Updating. The primary objective of the implementation schedule is to set actions for short-term programs. However, any integrated solid waste management plan will require periodic updating. There will continue to be significant changes in the technology for waste processing and material recovery. Also, there is a continuing need to monitor the performance of waste diversion facilities to verify their compliance with diversion standards set in the plan.

Therefore, to make long-term plans, the manager must
(1) monitor developing technology,
(2) maintain contact with the community and its resources,
(3) monitor existing standards and assess their continued need, and
(4) update the community waste management plan. It is often best to assign these responsibilities to a single agency.

11.5 Securing a site and obtaining permits

Once the need for facilities has been identified, a site must be secured at which each facility can be constructed and operated for its economic life. Securing a site for a facility, commonly called facility siting, requires the systematic use of community data to answer the concerns of its residents. Data identification and evaluation is done by a multidisciplinary team of design and operations specialists, environmental engineers, geologists, hydrologists, geotechnical engineers, and environmental assessment specialists.

Facility sitting will cause strong negative reactions in the community, because solid waste facilities of the past have not been good neighbors. In recent times, the old problems of litter, odor, and air pollution have been controlled to acceptable levels. However, the controls are too late to prevent negative public feelings caused by the old ways of processing and disposing of solid waste. Materials recovery and composting facilities, although accepted and welcomed by the public as better neighbors than municipal solid waste combusts or landfills, or landfills, are stuck with the legacy of past environmental problems.

Permits are obtained by responding to the requirements of the permit-issuing authority. The criteria to be met in siting a facility are derived from the permitting criteria set by regulatory agencies. The legal defense of selecting a site is based on the legal requirements for a facility permit as written in the regulations.

In this section, an approach is presented that will guide site selection and the obtaining of permits. The details of choosing a site and obtaining the necessary site permits is specific to each regional state and local communality, and those details are beyond the scope of this text. The approach has two parts: developing a strategy and interpreting legal requirements.

Strategy for Facility Sitting

A successful strategy is one that provides a facility site that has the support of the community. Community support starts with a broad base of group participation and data base.

Community Group participation. Everyone in a community generates solid waste, and the environmental consequences of its handling and disposal are broad based. One way to get community support is to involve community organizations in site selection. Many communities do this through a site selection task force. The strongest task force is one that is appointed by the local elected officials and that conducts its work under a narrowly defined set of objectives. If a task force is used, it should have members selected from a broad rang of the community. Community service organizations that might provide members include women’s association, Chamber of commerce, environmental groups, and local affiliates of larger groups like the

Lions Club. Local agencies should be represented on the task force by senior staffs who are recognized as decision-makers.

The task force for facility siting can be expected to have both proponents and opponents for every site. Therefore, it is important to have sufficient and accurate data to the members in a timely manner. In general, the earlier the task force meets in the siting process, the better the probability of getting a site. In many instances, the task force should help the agency staff set the site selection criteria.

Technical, Scientific, and Economic Data Base. Facility site selection requires an organized approach to locate a site and develop a data base to justify its selection. The steps in the sitting process include

(1) identification of the feasible sites,

(2) the development of technical, scientific, and economic criteria for site comparisons,

(3) evaluation and comparison of feasible sites to select the best sites for detailed analysis, and

(4) a thorough investigation and data accumulation on the best sites to recommend the final site.

While getting background data on sites, the siting team will be developing and choosing criteria for site evaluation. Although there are many ways to get and present criteria, the most useful presentation is one that fits the level of understanding of the broad community.

The following broad categories of criteria are recommended.

- Political boundaries
- Regulatory
- Environmental

Surface water

- Ground water
- Natural habitat
- Land use
- Air quality

- Social/cultural
- Aesthetic
- Technical
- Economic

The criteria will be used both in an initial screening of sites and in final site selection. Assigning numeric values to each criterion is an easily understood and practical way to demonstrate their use to the public and reviewing agencies. A commonly used rating scale is from 1 to 10, where 1 is the least desirable value and 10 is the most desired value.

Because solid waste facilities are not accepted as good neighbors, it is important to offer numerous sites for evaluation. Initial screening should be done in the least expensive way, leaving the most costly studies and data gathering to the final site selection activities. Providing a rational explanation of why sites were excluded is essential to a successful initial screening.

Strategy for obtaining permits

Solid waste facility permits will be required from federal, state, and local agencies.
In general, local permits will be the easiest to get and federal permits will be the hardest to get. The strategy to obtain permits varies with the regulations, but certain strategic steps to permitting are useful in most circumstances. A strategy should include
1) identification of permit-issuing agencies,
2) issuing agency involvement, and
3) responding to conditions set during the permit hearing process.

Permit-issuing Agencies. The number and types of permits is determined by the type of facility. Typical solid waste facilities and the types of permits requited are reported in Table 8-2. The federal permits are first priority, with state and local permits requiting conditions equal to or more stringent than federal levels. The most commonly encountered federal permits are from the Environmental Protection Agency (EPA) for air discharges from incinerators and from the Corps of Engineers for landfills. For the facility planner the critical issues are identifying the required permits for a facility and defining the permit issuing schedules.

Issuing Agency Involvement. Agency staff is responsible for implementing procedures for issuing permits. In many instances the agency will have a written guide for making permit applications. The applicant should follow the guide but should also establish a contact within the permitting agency. Through personal contact, the applicant can determine the agency requirements for detailed information. The applicant can review other applications for similar facilities and set details with the agency on matters such as number of drawings, sequence of reviews, and schedules. With this information from the issuing agency, the applicant can set a scope of work and provide the funding for a permit application.

Table 11-3 Typical solid waste facilities and types of permits for construction and operation

Facilities	Types of permits
Combustor	Same as the permits required for energy recovery, except no power generation permit is needed
Composting facilities	Conditional use permit; solid waste facilities permit in some states
Energy recovery facility	Conditional use permit; power generation permit; NPDES permit for wastewater discharges; appropriate air permits; permit to construct; solid waste facilities permit; ash and residue disposal permit
Landfill for municipal solid waste	Conditional use permit; wastewater discharge permit; storm water discharge permit; solid waste facilities permit
Materials recovery Facility	Conditional use permit; solid facility waste facilities permit in some states
Methane gas recovery	Only a power generation permit and a plant NPDES permit for air discharge are added to the landfill permits if the landfill is active; if the plant is installed at an inactive or close landfill, the required permits are power generation, NPDES, and wastewater discharge
Transfer station	Conditional use permit; permit to construct; solid waste facilities permit

Source: Adapted from Ref.6

Responding to Permit Conditions. The issuance of a permit is the end of a negotiation process between the applicant and the issuing agency. For the benefit of both parties, this negotiation is often done at the reconstruction phase and again prior to full operations. The permit to construct often contains conditions that must be met during contraction. The applicant must work in a cooperative spirit to respond to conditions placed on the facility by the agency or face the risk of an unsuccessful application. The agency has a legal responsibility to ensure that the facility is in conformance with regulations; the agency cannot act as an advocate for the facility. The legal versus advocacy position is most apparent during public hearings regarding the permit.

Interpreting Legal Requirements.

A land owner or group opposing the site or the permit for the facility will use all possible legal means to defeat the facility. The applicant must understand and follow the legal requirements. A legally sound and defensible siting study and permit application will result in the selection of an acceptable site.

The legal requirements are found in the regulations of federal and regional state agencies and in the ordinances of local agencies; in most instances, the proposed facility will not be the facility for which the laws were written. Interpreting the law in terms of the facility is the means of getting regulatory approvals. The most often used laws for challenging a siting study or a permit application are the environmental impact statement (EIS) and land-use Zoning. In the following sections a brief overview of each is presented.

Environmental Impact Statements. The National Environmental policy Act (NEPA) gave a legal basis for arguing the environmental impacts of a facility. In most states, the NEPA requirements are met in state laws. The EIS is the document that records the environmental impacts of the facially.

The cost of preparing an EIS varies with the type of facility and the location of the site. Because of cost and perceived delays for hearings, the applicant may narrowly interpret the law to benefit the facility and ask the lead agency for a negative declaration on the impacts of the facility. A negative declaration is one of the actions allowed under the law. It is a finding that the facility has insignificant impacts and can proceed without the detailed studies and data gathering of a full EIS. If the negative declaration is used for expediency only, it is a candidate for successful legal challenge. Since solid waste facilities have many impacts on the urban and rural environment, the facility applicant and the lead agency should carefully review and interpret the legal requirements before selecting the type of environmental document.

Land-use Zoning. The controlled development of land use is done through zoning. Not all communities have zoning laws, but in those that do, the laws are a means of opposing a nonconforming land use such as a landfill. Zoning is evaluated during the issuance of a conditional Use permit (CUP) for the facility. The CUP will contain conditions agreed to by the applicant during interoperation of the law.

Management Issues. The major management issues to be addressed during the study are the following:

1. What is the best arrangement of landfills to receive wastes from all cities within the region?

2. What processing and recovery equipment should be installed so that resource recovery is developed?

11.6. Review Questions

1. Contact the agencies responsible for solid waste management in your community. Identify all plans and program changes undertaken by each agency within the past years. List the policy programs requiring political decisions and the programs acted upon without political decision.
2. Refer to Fig.11-1.Which of the activities will be most difficult to achieve in your community?
3. What public information means are used by solid waste management agencies in your community? Randomly select the names of five community residents and as them if they are a ware of solid waste management issues on the local level and on national and international; levels.

4. Waste diversion has added a focus to planning. Identify where in a plan waste diversion can be quantified as to cost and quantity.
5. What agencies in you communities are part of a team for finding sites for action? Give some examples of a strong implementation schedule .Who is accountable?

GLOSSARY

Aerobic: containing organisms which need free oxygen; living or active only in the presence of free oxygen.

Anaerobic: Unable to live in the presence of free oxygen, but obtaining oxygen by breaking down complex organic compounds.

Ash residue: are waste products of coal and other fuels .They are non putrescible.

Composting: the controlled biological decomposition of organic solid waste under aerobic conditions.

Contamination: the presence of an agent of infection on a body, articles or substance.

Dead Animals: are big and small animals that are putrescible if not removed and disposed properly.

Domestic wastes: comprise kitchen wastes, ashes from fires, broken utensils and worn out clothing.

Garbage: Putrescible solid waste including animal and vegetable wastes resulting from the handling, storage, sale, preparation, cooking, or serving of foods.

Health-care facility waste: includes all the waste generated by health-care establishments, research facilities, and laboratories. In addition, it includes the waste originating from "minor" or "scattered" sources-such as that produced in the course of health care undertaken in the home.

Hazard: some thing likely to cause damage or loss; a danger or risk

Incineration: burning process of burnable wastes in an incinerator, to reduce the volume of the waste and sometimes change it to ash.

Incinerator: A facility designed to reduce the volume and weight of solid waste by a combustion process with or without a waste heat recovery system. It is an apparatus which enables refuse to be burnt with the minimum expenditure of fuel

Industrial wastes: are wastes resulting from manufacturing processes. Some of these wastes are putrescible and causing obnoxious odor and may create health hazard.

Infectious waste: a waste (solid) which is suspected to contain pathogens (bacteria, viruses, parasites, or fungi) in sufficient concentration or quantity to cause disease in susceptible hosts.

Integrated solid waste management: A practice of disposing of solid waste that utilizes several complementary components, such as source reduction, recycling, composting, waste - to - energy, and land fill.

Leachate: A liquid resulting from precipitation and percolating through landfills containing water, decomposed waste and bacteria.

Night soil: are excreta that have been collected from box, toilets and privies.

Putrescible wastes: are wastes that are decomposable by bacterial actions.

Recycling: A resource recovery method involving the collection and treatment of a waste product for use as raw material in the manufacture of the same or another produce.

Refuse: All putrescible-or non putrescible waste material that is discarded or rejected, including garbage, rubbish, incinerator residue, street cleanings, dead animals, and offal.

Resource recovery: A term describing the extraction and utilization of materials that can be used as raw material in the manufacturing of new products, or that can be converted into some form of fuel or energy source.

Rubbish: are all non putrescible wastes except ash. It consists of both combustible and non combustible wastes.

Sanitary landfill: A method of disposing of refuse on land without creating nuisances or hazards to public health or safety.

Solid waste: are waste materials ,not including liquid wastes .A WHO technical committee defines solid wastes as " useless", unwanted or discarded materials that arise from man's activities and are not " free floating.

Solid waste management: is the process by which workable alternative programs and plans are developed to solve solid Waste problems.

Source Reduction: Refers to reducing the amount of waste generated that must eventually to be discarded, including minimizing toxic substances in products, minimizing volume of products, and extending the useful life of products.

Source separation: The segregation of various materials from the waste stream at point of generation for recycling.

Street sweeping : are consists of materials worn out from street surface, deirts and other materials dropped or worn away from vehicles, leaves, sweepings side walks.

Transfer station: A facility with structures, machinery, or devices that receives deliveries of solid waste by local collection vehicles, and provides for transfer to large vehicles that deliver the waste recycling, treatment or disposal site.

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